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INDIAN JOURNAL OF POWER & RIVER VALLEY DEVELOPMENT

HIRAKUD PROJECT NUMBER

VOL. VI. NO. 10

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HIRAKUD DAM, POWER HOUSE AND LAKE

YET another glorious chapter is opened in the history of resurgent India—the mighty Hirakud Project is complete now! This huge dam with its elaborate network of canals will irrigate 2,539,094 acres of arid land and generate 1,95,000 kws. of electricity to turn the wheels of industry and light up thousands of homes.

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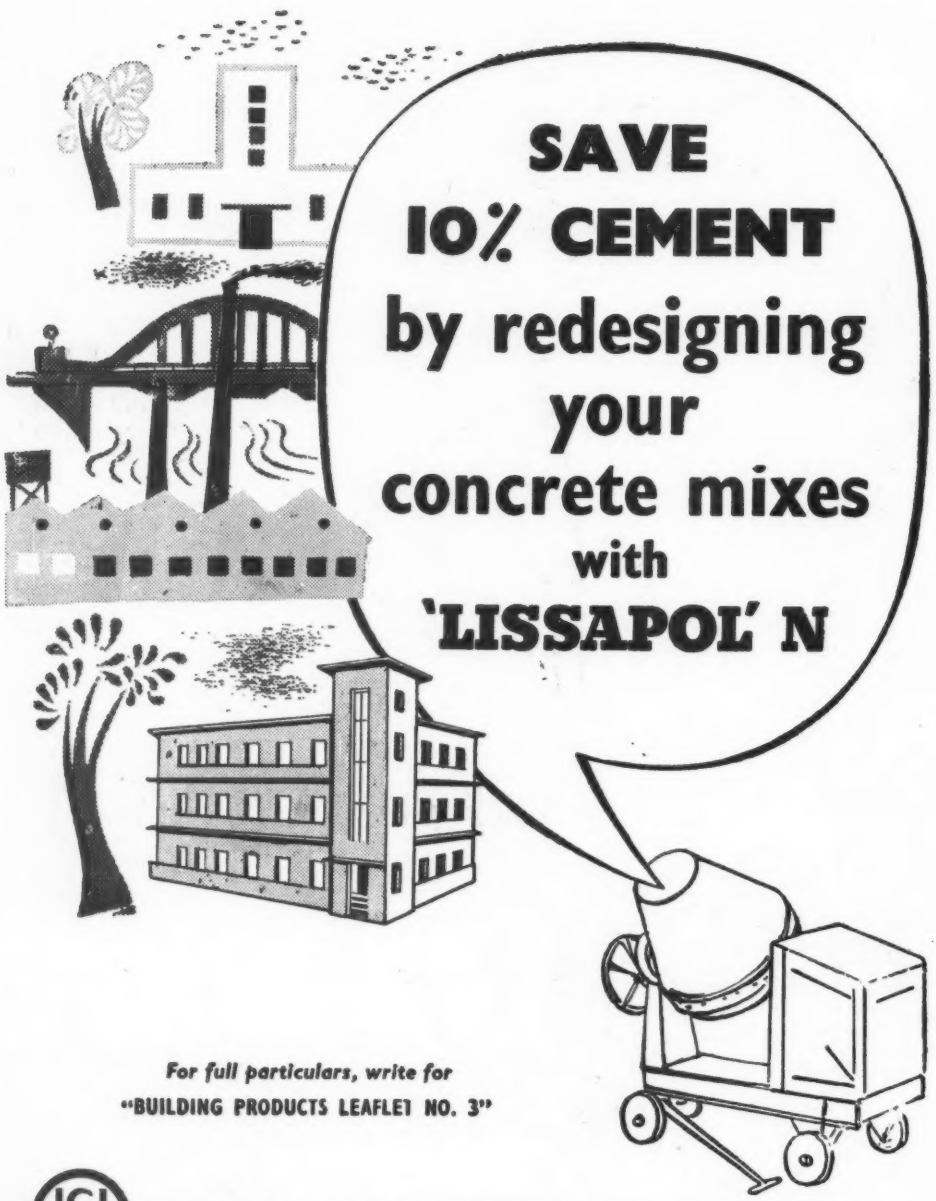

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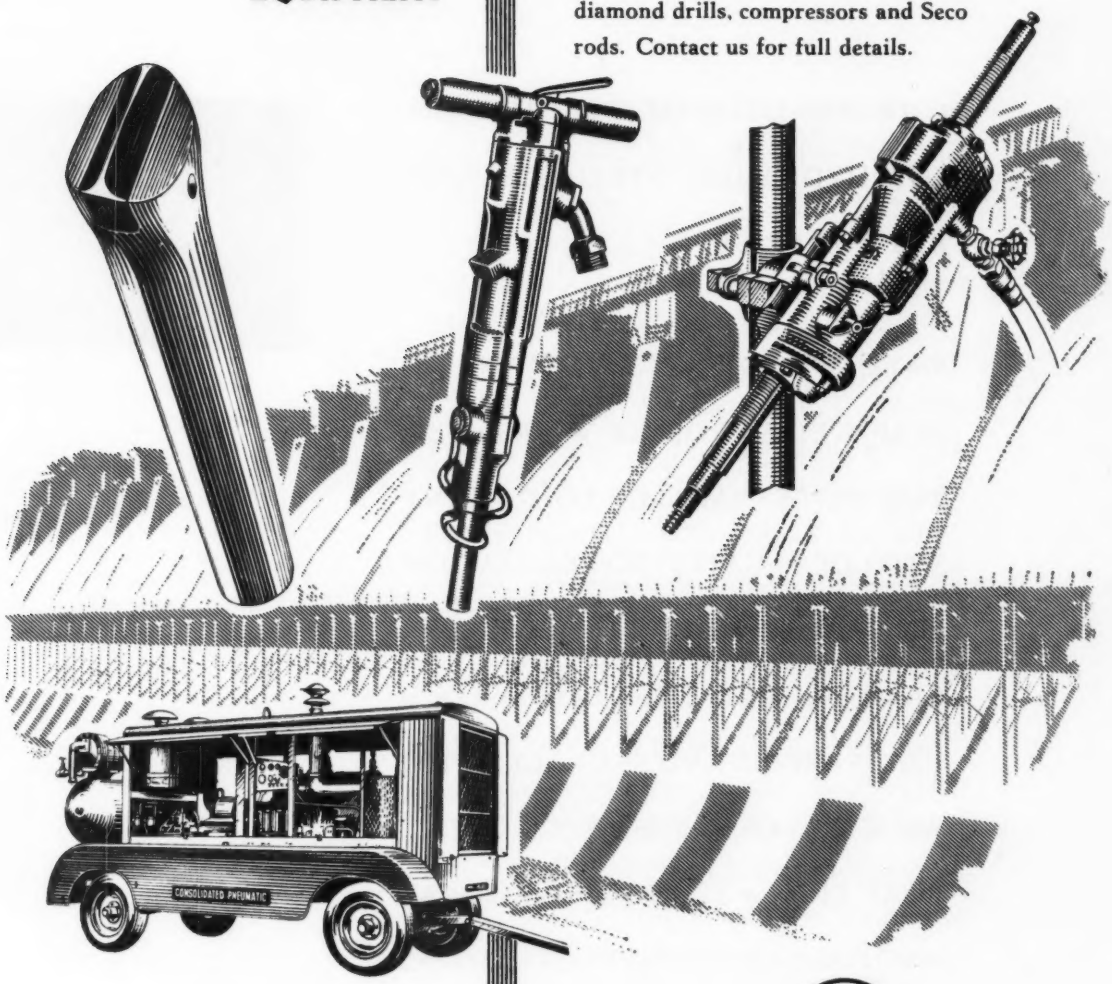

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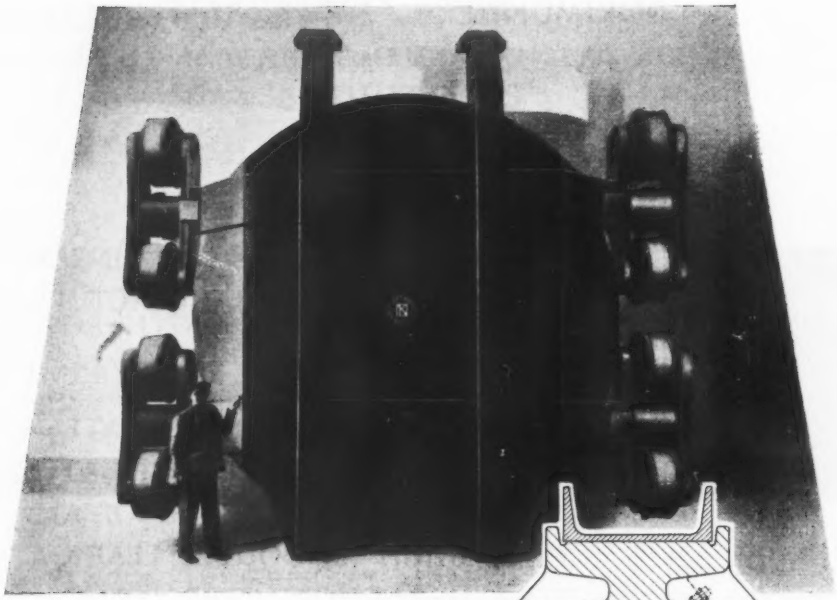

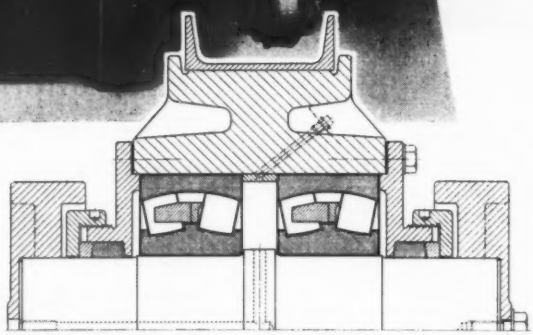

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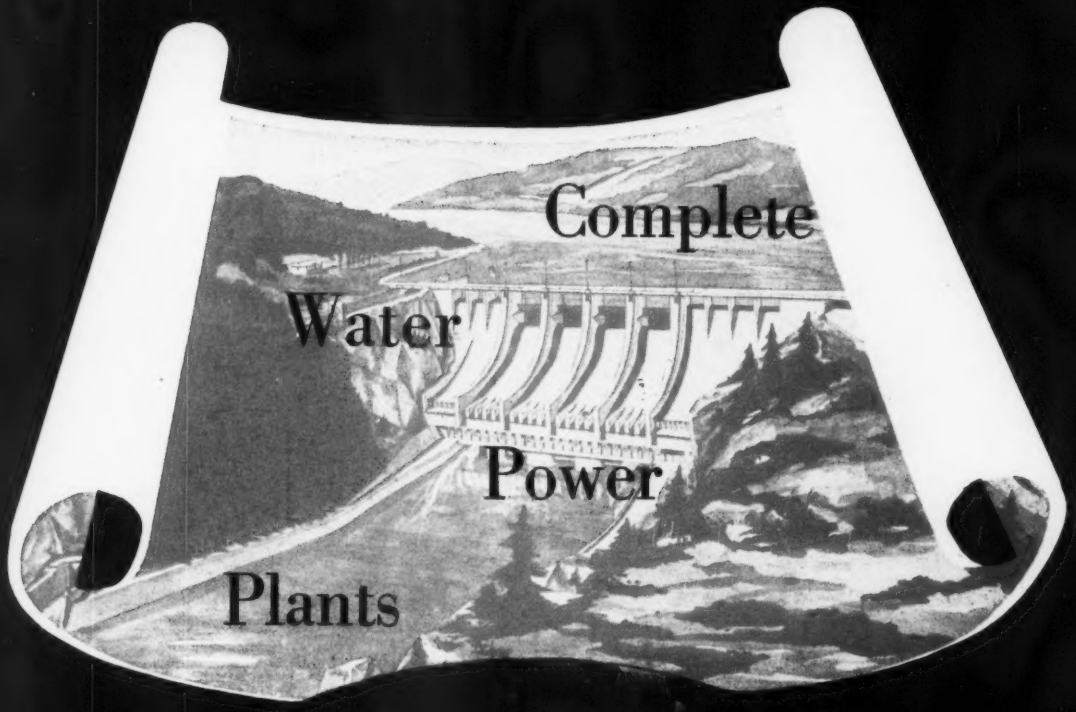

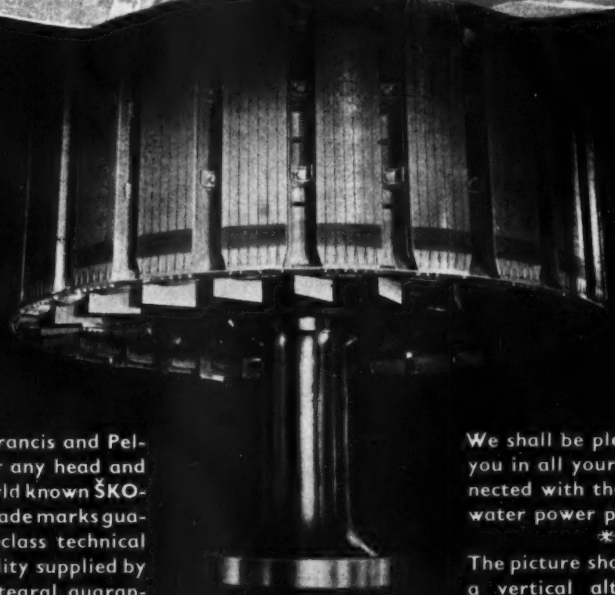

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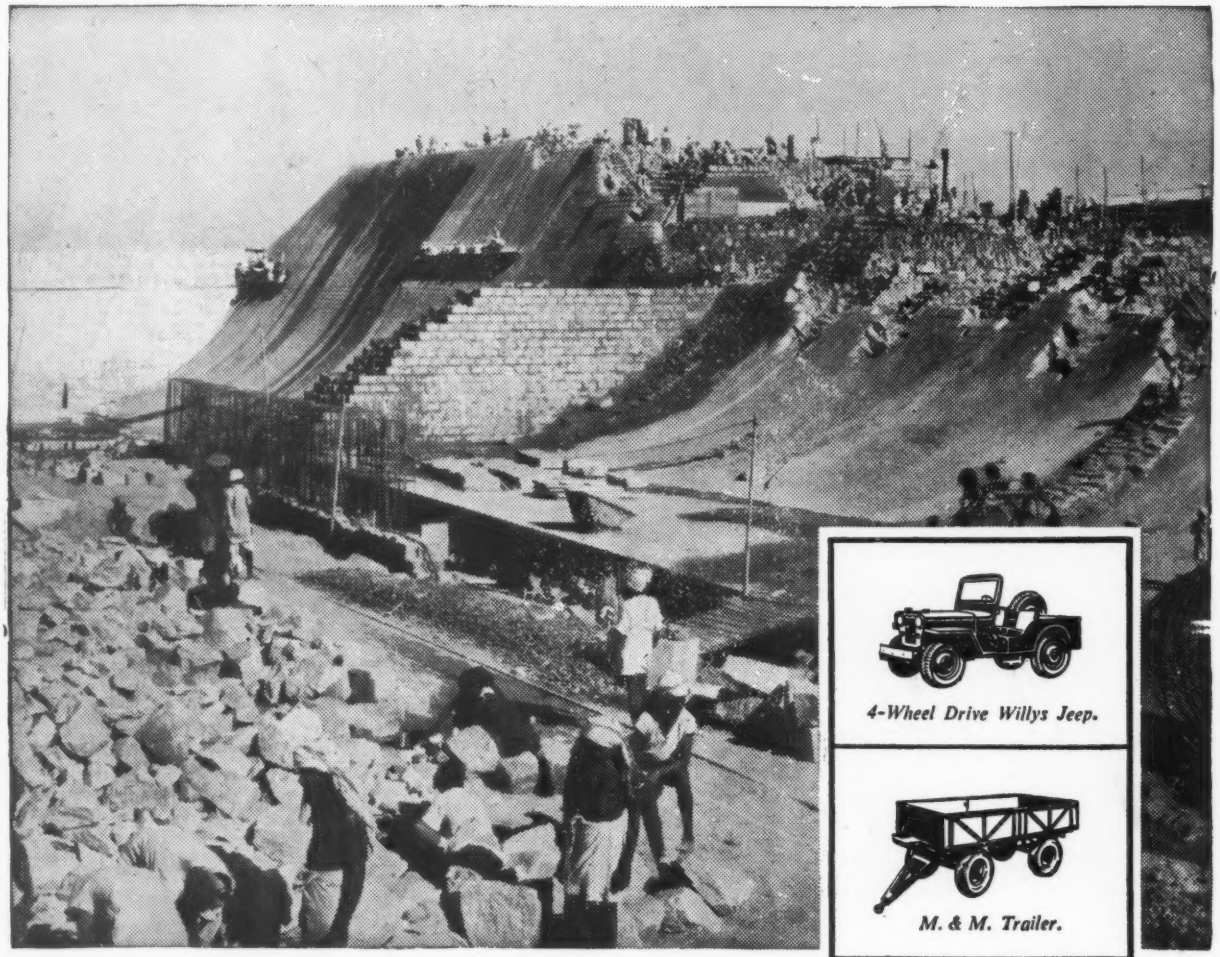

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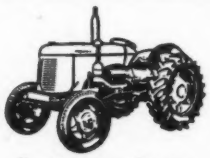

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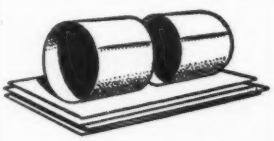

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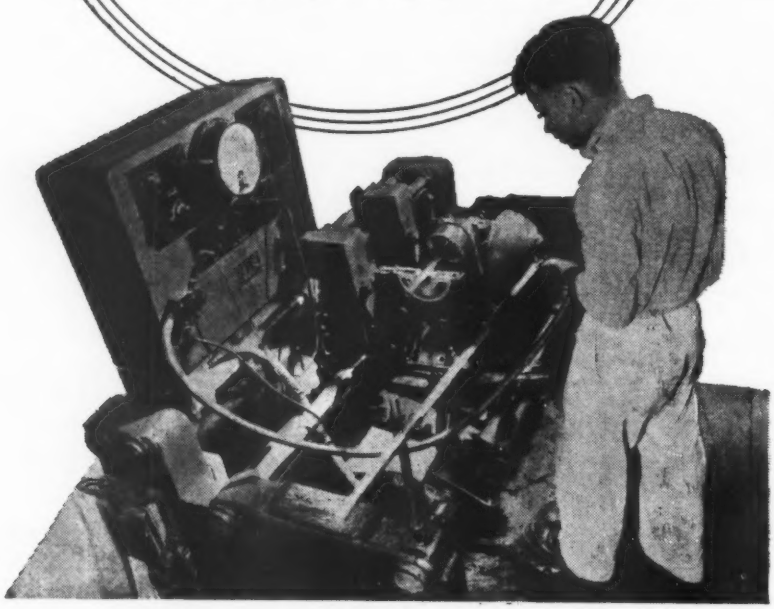

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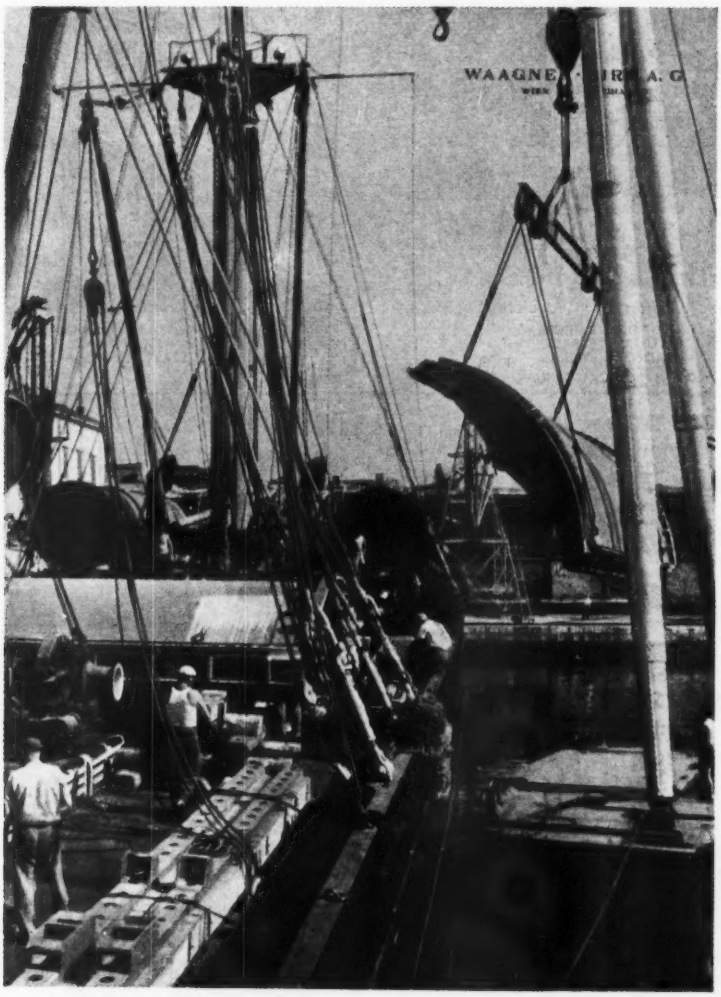

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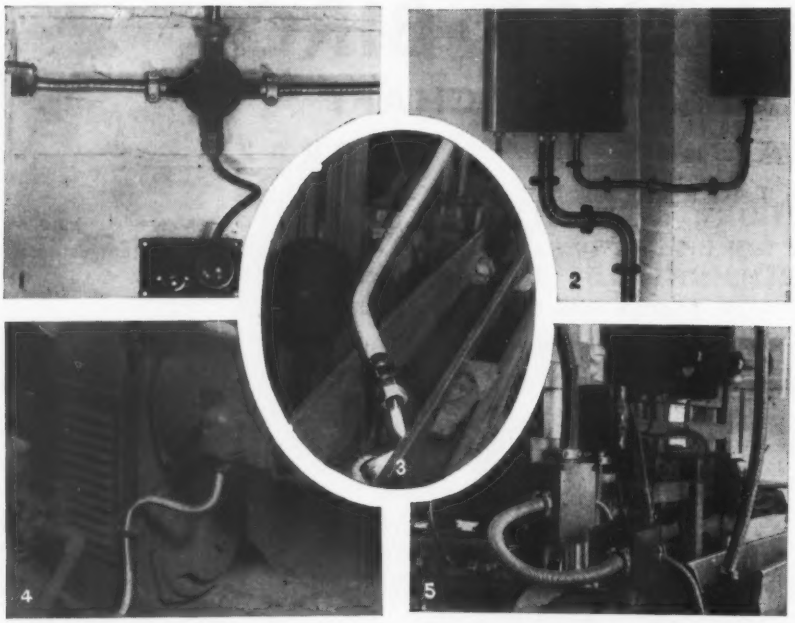

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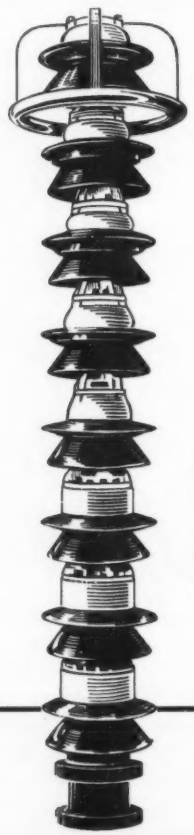

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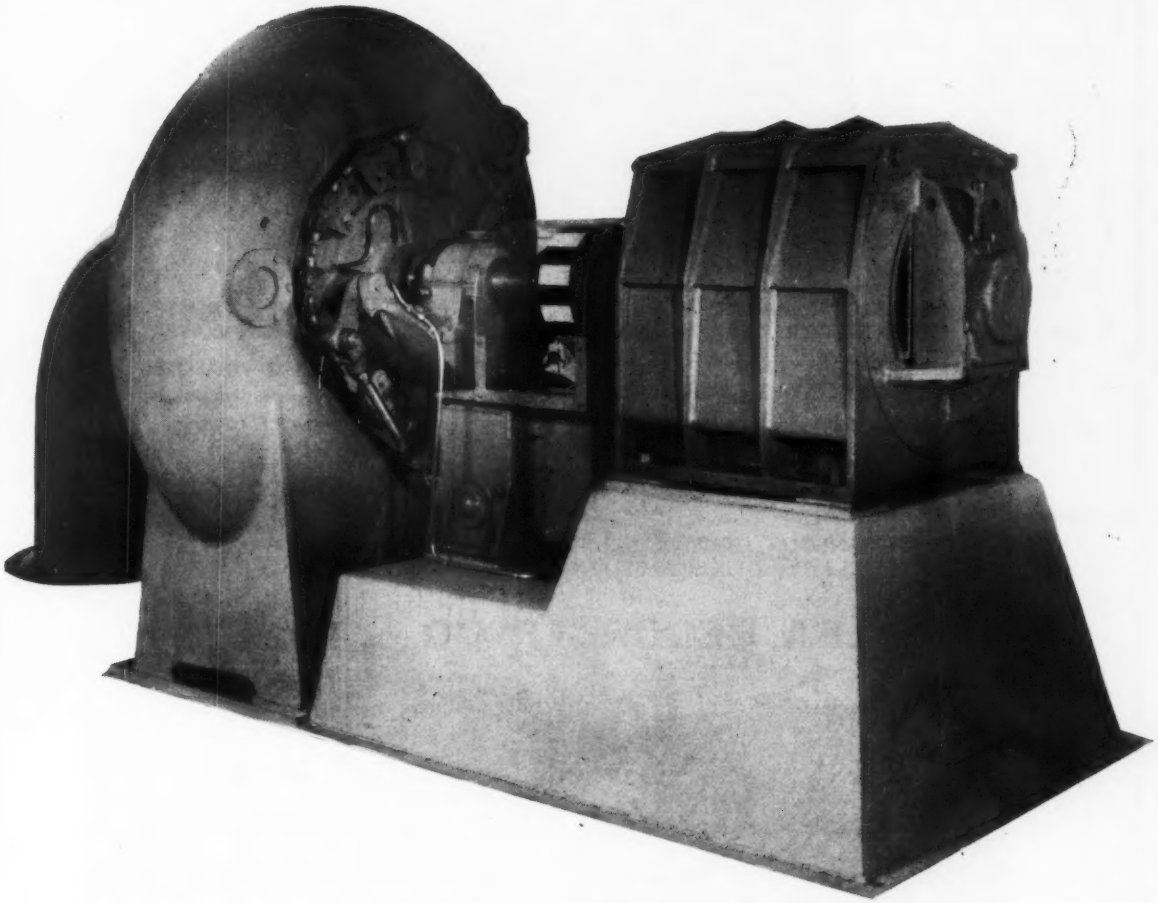

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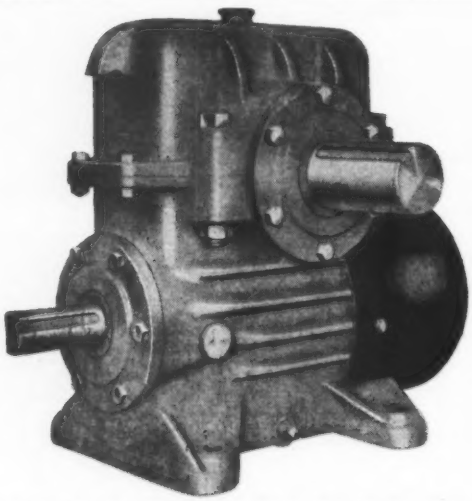

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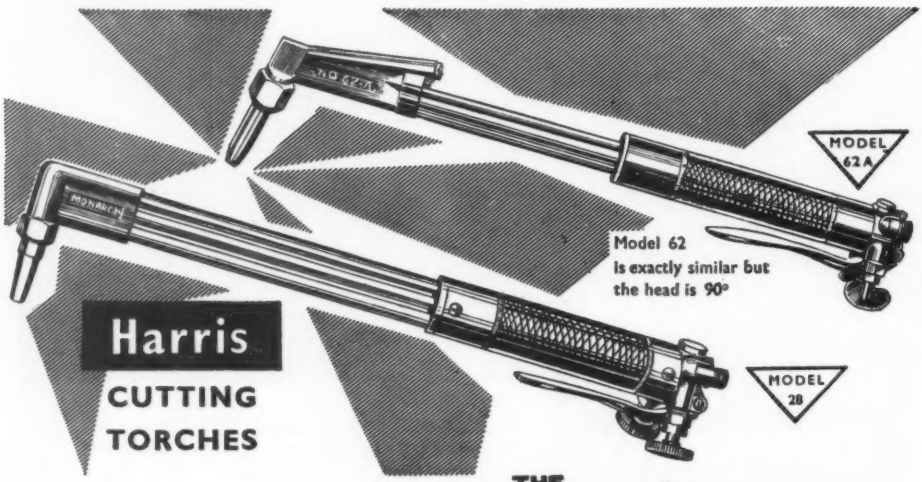

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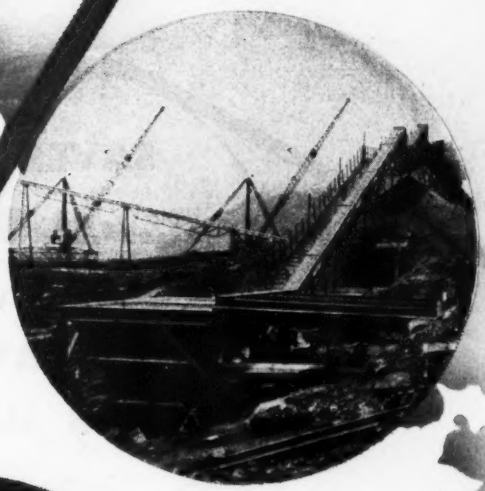

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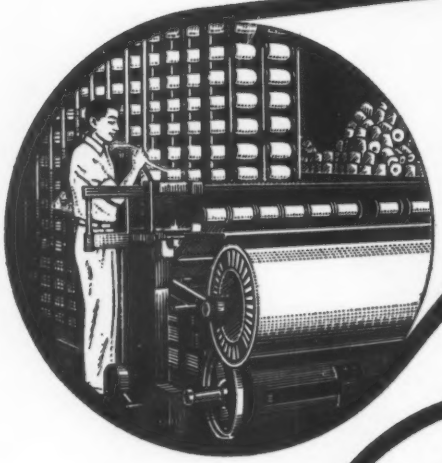

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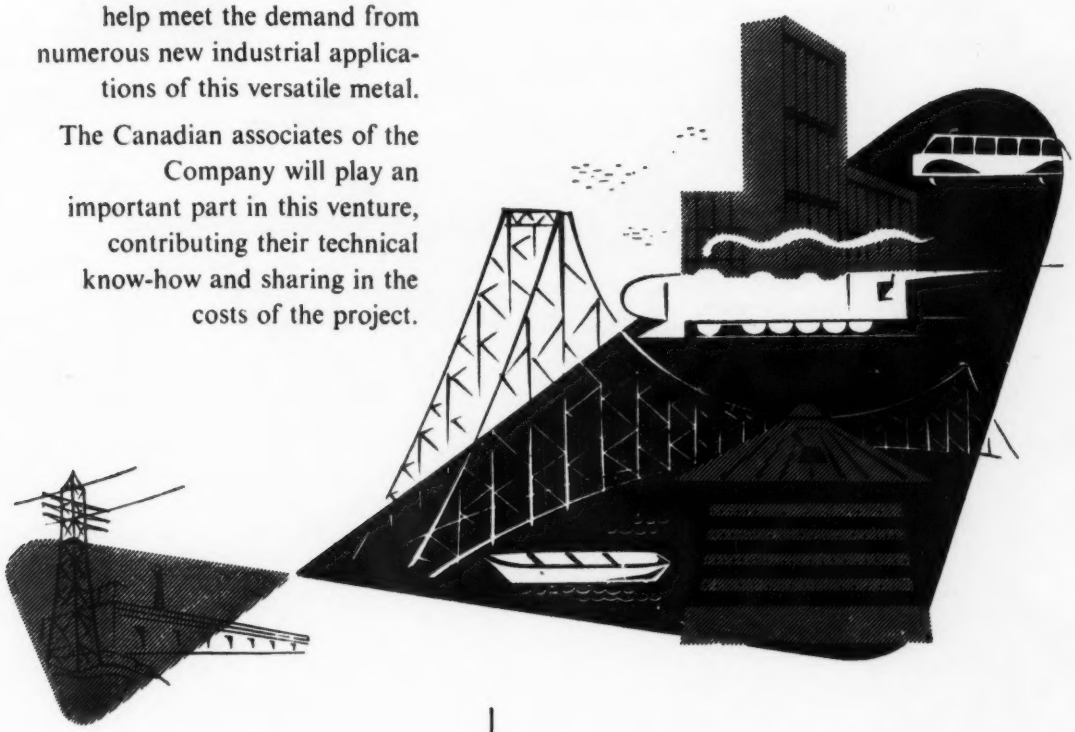

The Hirakud smelter will mark another milestone in the march of progress towards a new aluminium age.

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At Bhakra, where the Sutlej has cut deep gorges in the mountains and strewn its banks with boulders, an endless conveyor belt carries these aggregates to the location of the dam. The conveyor system, the longest in India, is operated with push-button ease. The belt was made by Dunlop in India.

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DRAC-31

POST INSULATORS for the Hirakud Dam project

S.P.P. Post Insulators were supplied for the 132kV. outdoor switchgear on the Hirakud Dam Project.

S.P.P. Post Insulators have also been used on all the major hydro-electric projects in India, including the following:—

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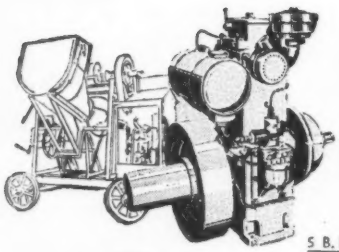
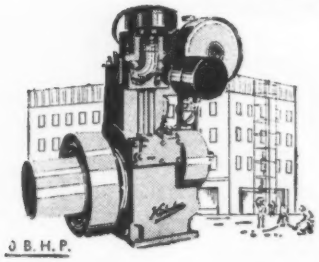
Machkund Scheme
North Calcutta Scheme
Pallivasal Scheme
Tungabhadra Scheme
Kunda, Madura, Mettur Dam, Moyar, Papanasam and many other substations on the Madras Grid.



5 B.H.P.

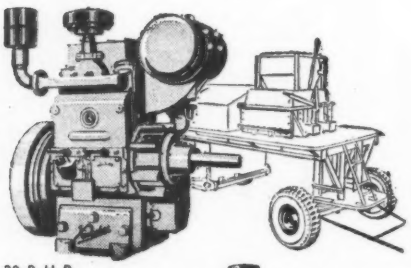
Choose your Construction Machinery fitted with



9 B.H.P.

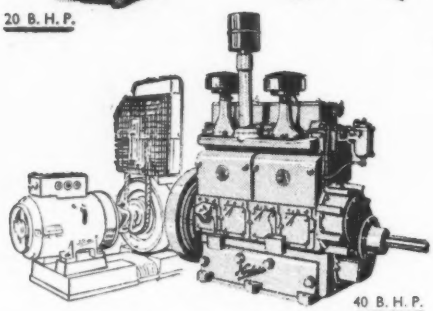
Kirloskar

DIESEL ENGINES



20 B.H.P.

KIRLOSKAR diesel engines are used for all industrial and engineering purposes. Outstanding reliability, rigid construction and efficient performance—the outcome of years of experience in sound design and workmanship—make Kirloskar diesel engines popular in the field of constructive engineering. These engines are designed in such a way that they can be handled easily even by unskilled labour.



40 B.H.P.

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KOEL 6-1 56

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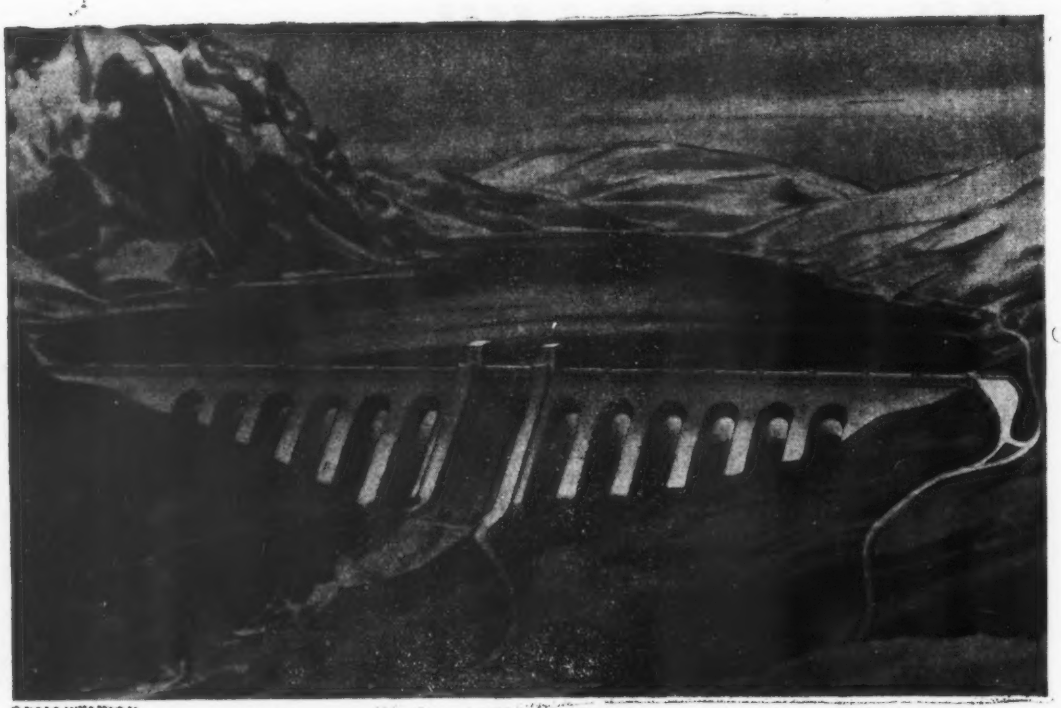
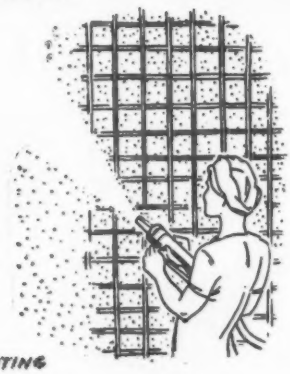
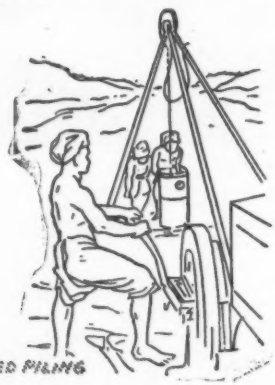


CEMENTATION



GUNITING



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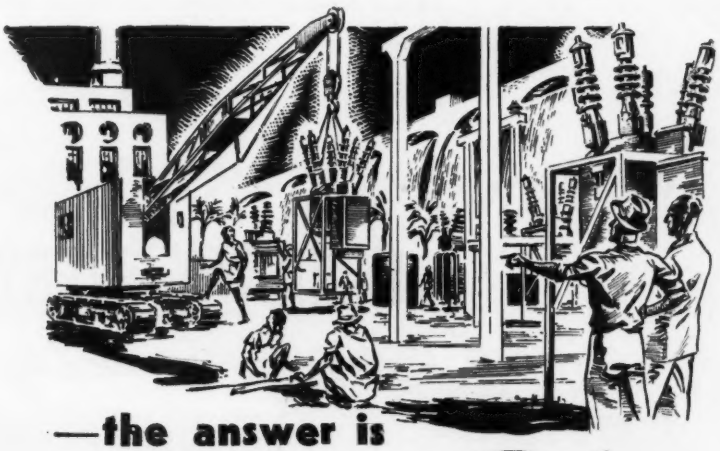
When the call is for SWITCHGEAR—

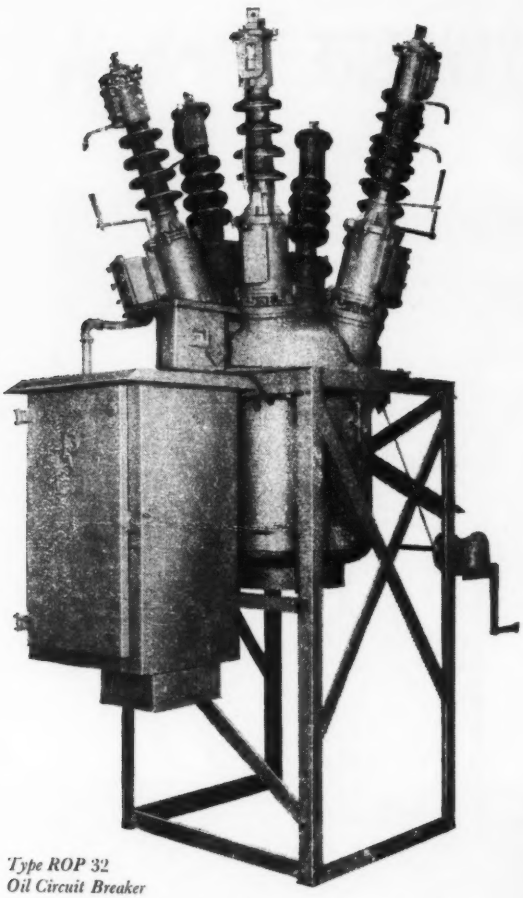


—the answer is

Ferguson Pailin

When the dam is built and the major constructional work completed the task of installing the electrical plant and the equipment must be undertaken.

Ferguson Pailin have supplied switchgear for indoor and outdoor stations, including major hydro-electric schemes the world over. 'F. P.' is synonymous with first-class design, manufacture and performance of this essential equipment, ranging from extra high voltage switchgear for main grid supply systems down to low voltage switchgear for industrial purposes.



Type ROP 32
Oil Circuit Breaker

Two examples of 'Ferguson Pailin' switchgear, for varying duties, are illustrated here. They are :—

ROP 32 OIL CIRCUIT-BREAKER

Wherever 22 kV or 33 kV outdoor oil circuit-breakers for breaking capacities up to 750 MVA are required the merits of the 'ROP 32' breaker should be considered.

The design of this breaker provides for the optimum protection against adverse working conditions peculiar to countries in various parts of the world as well as maximum resistance to the effects of fluctuating temperatures and humidity.

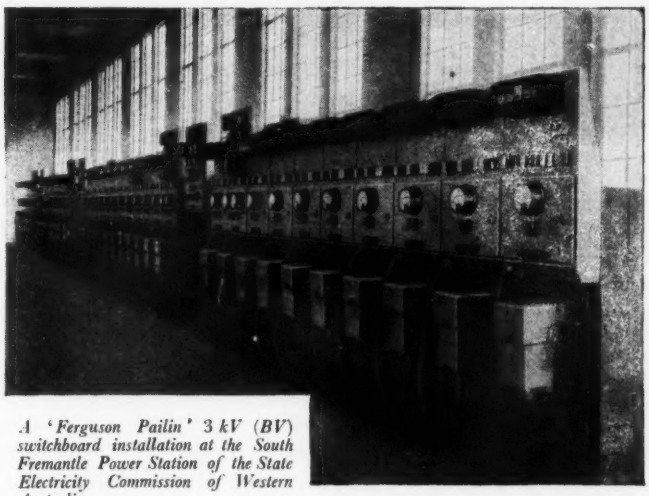
The versatility of the 'ROP 32' makes it remarkably adaptable to local requirements. Complete dependability and reliability make it a natural choice for incorporation into any scheme involving the transmission of power at 22 kV or 33 kV.

The circuit-breaker tank is of cylindrical shape and all three phases are brought into one tank, permitting the use of smaller framework thereby achieving compactness.

'BV' SWITCHGEAR

'Ferguson Pailin' Type BV switchgear is of the completely enclosed metalclad type. It is constructed on the unit principle and can readily be extended by units of similar rating, or by metalclad oil switches.

Vertical isolation of the breaker ensures minimum space requirements of the unit, whilst adequate interlocks safeguard against mal-operation.



A 'Ferguson Pailin' 3 kV (BV) switchboard installation at the South Fremantle Power Station of the State Electricity Commission of Western Australia.

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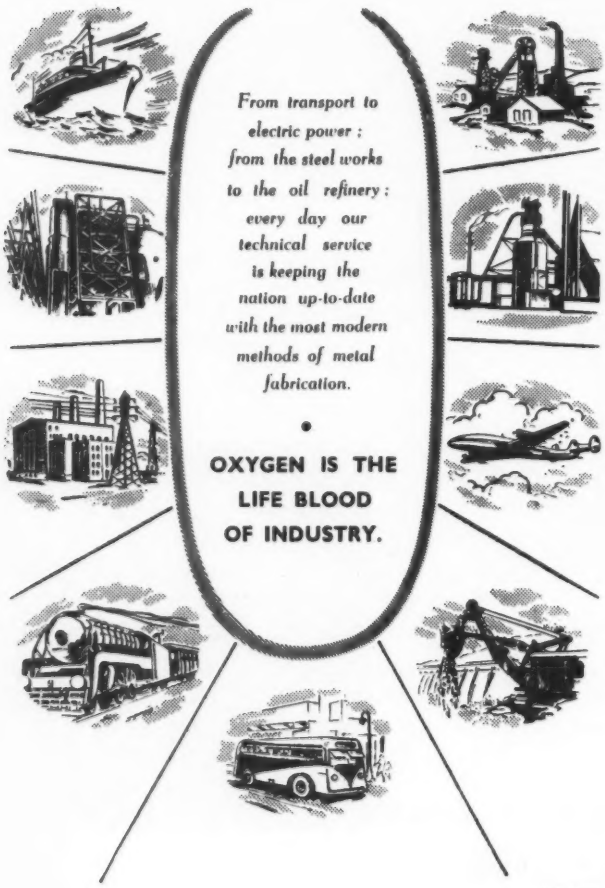
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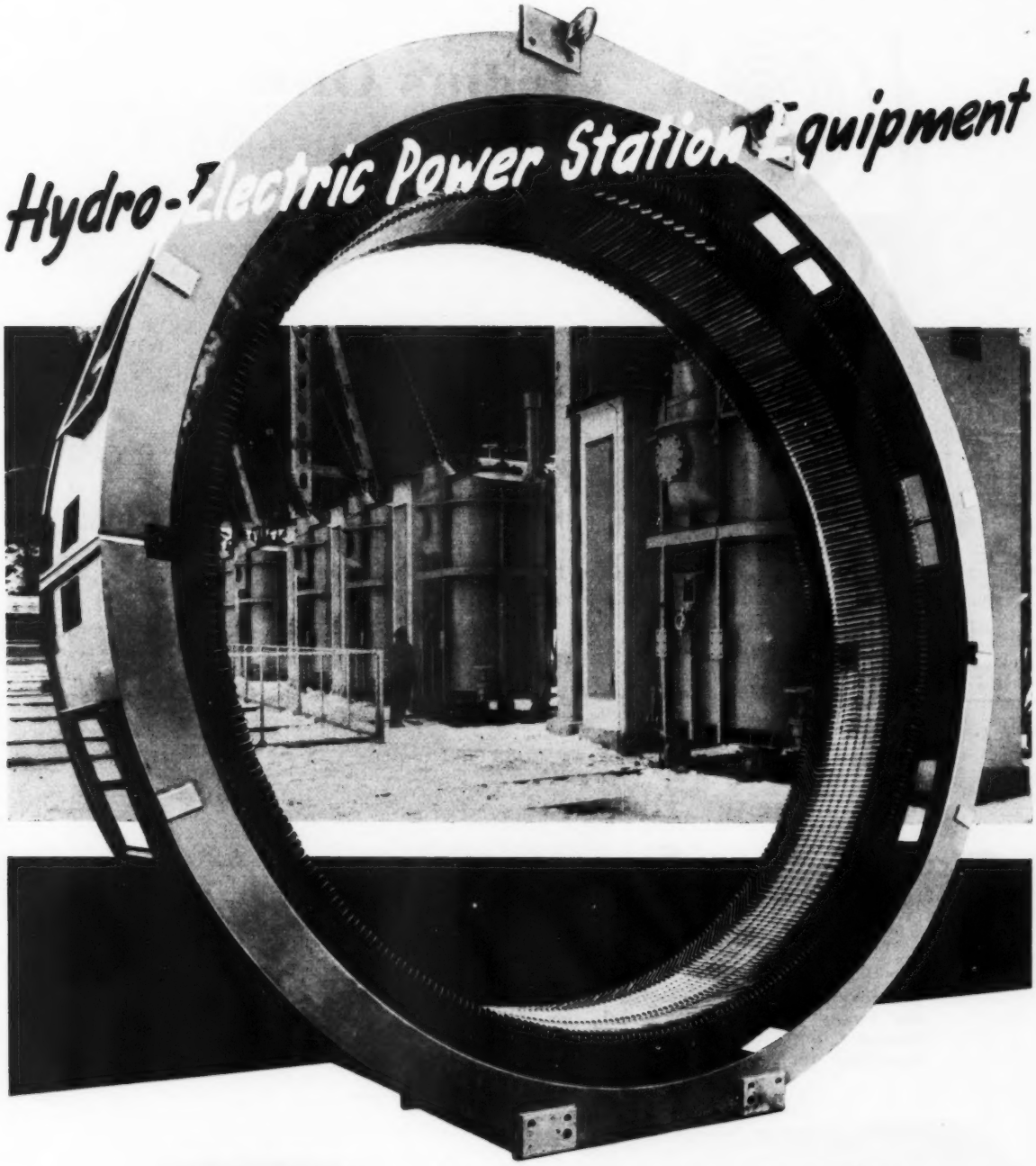

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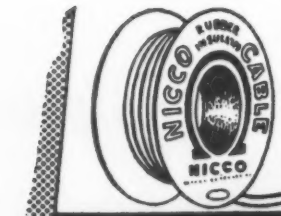

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HIRAKUD DAM
Inauguration!!

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"NGK" Insulators have been used in Hirakud, Nangal, Machkund, Damodar Valley and all the main power projects in India.
Besides India, NGK Disc Insulators have also been supplied to Swedish Power Board (Sweden) and Bonneville Power Administration (USA) for their ultra high tension transmission lines.

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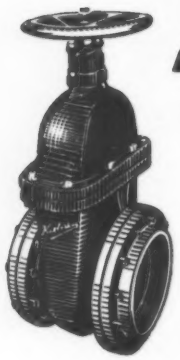

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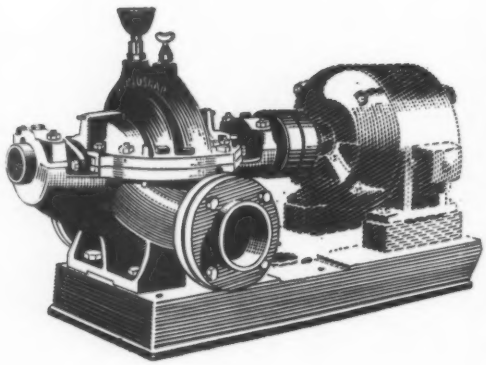

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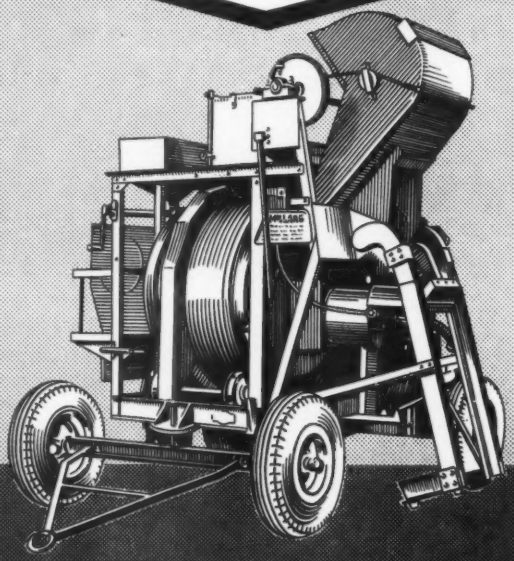

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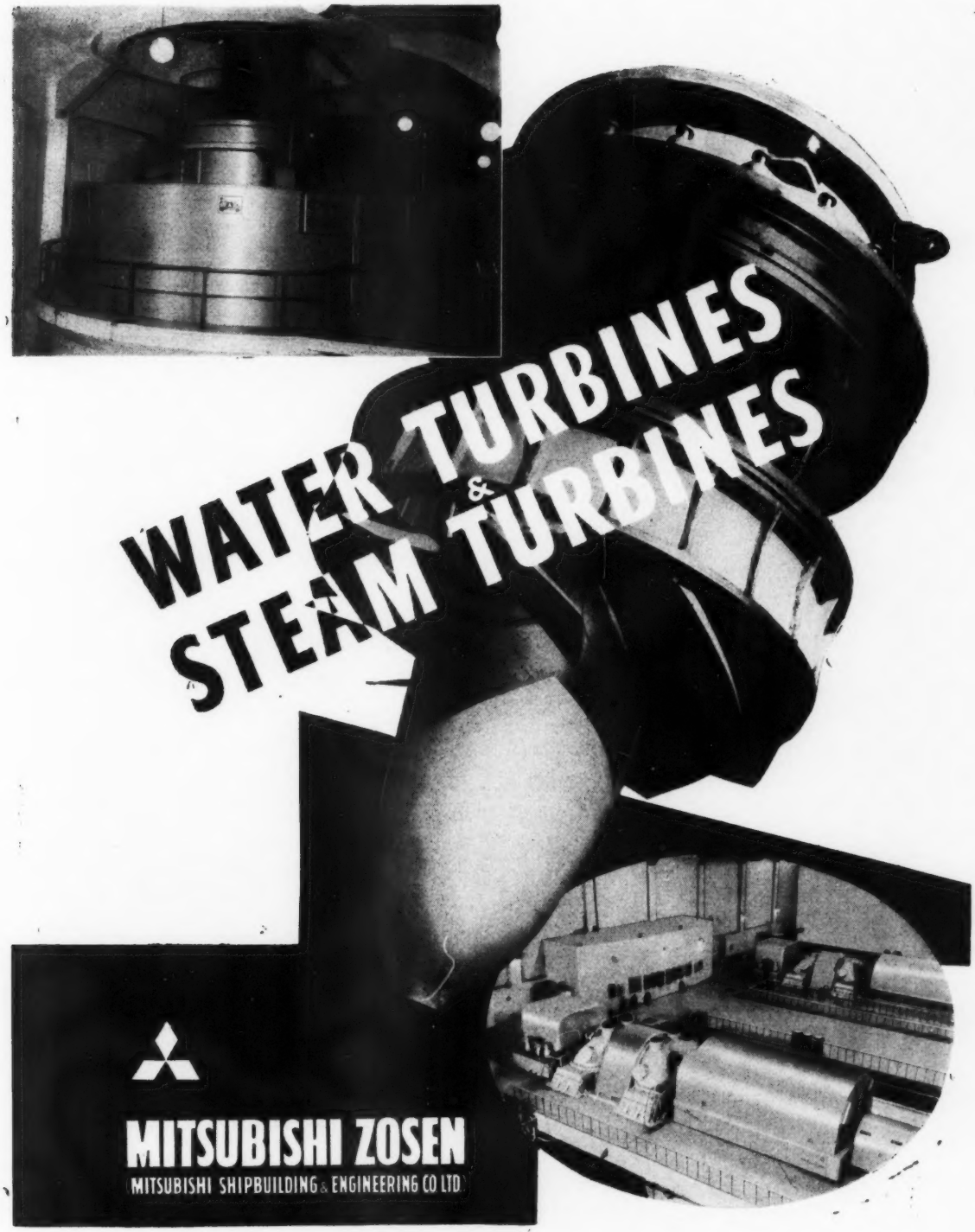

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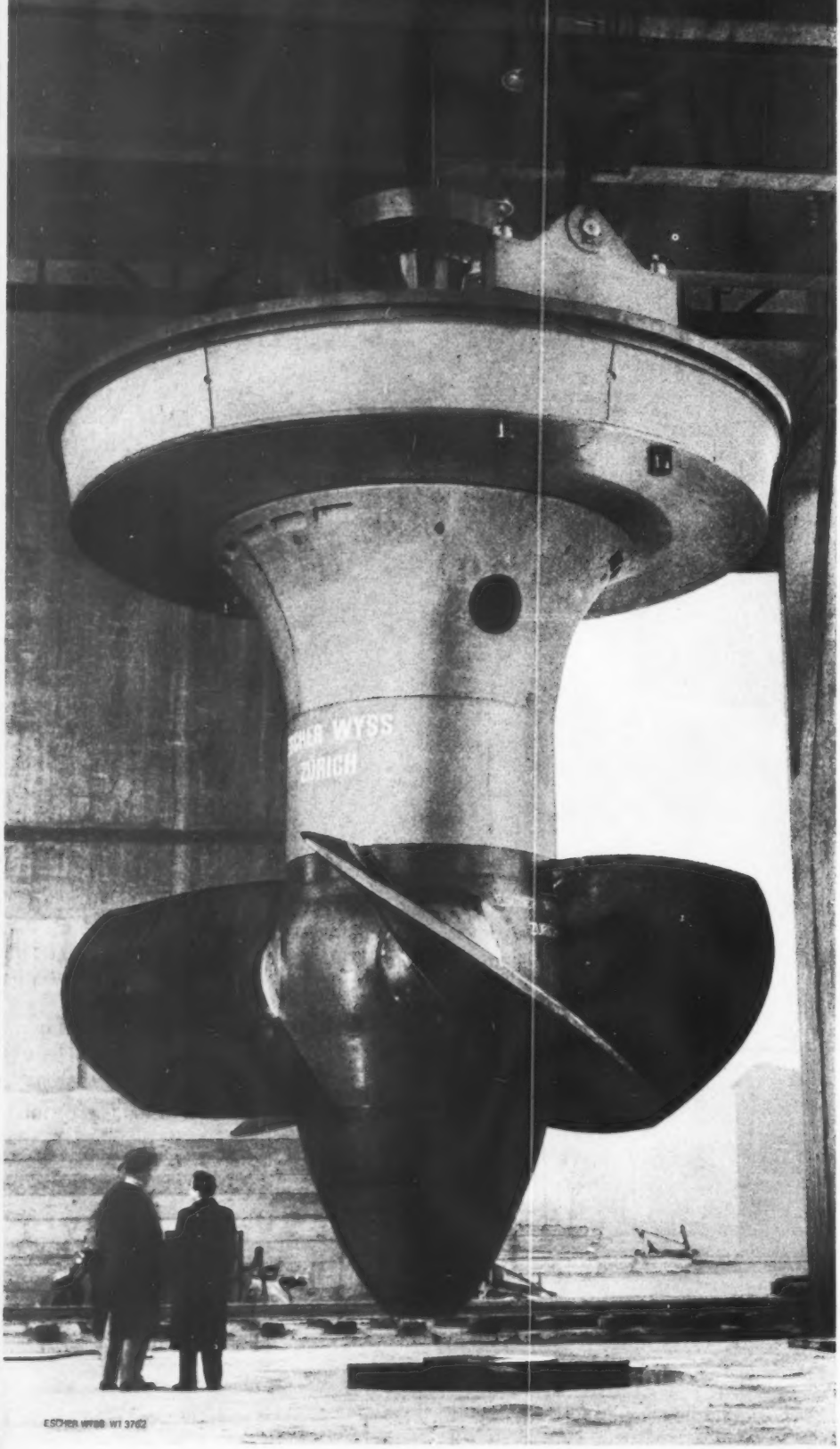

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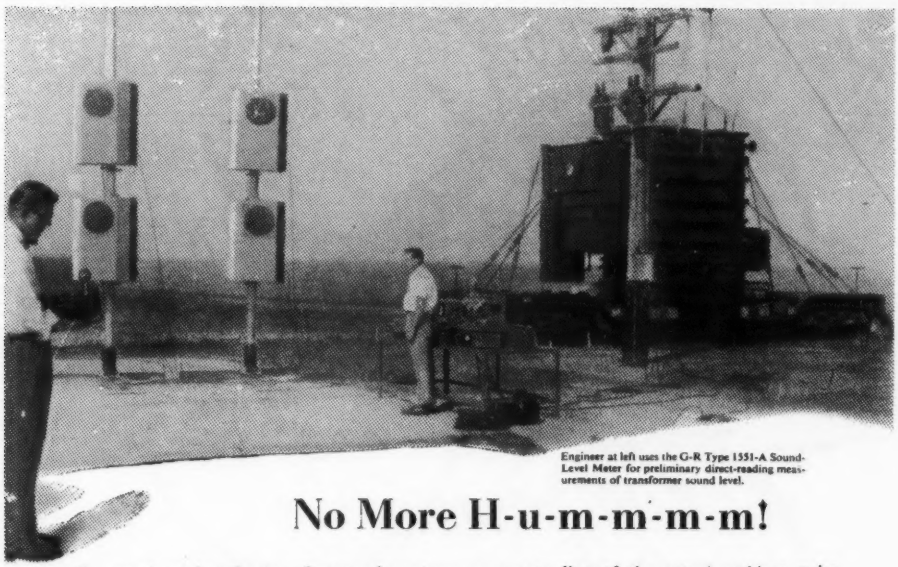

Engineer at left uses the G-R Type 1551-A Sound-Level Meter for preliminary direct-reading measurements of transformer sound level.

No More H-u-m-m-m-m!

By superimposing the transfer sound-spectrum on a recording of the actual ambient noise existing at the proposed site, the complete response of the transformer can be accurately predicted. Engineers faced with the problem of hum from power transformers in populated areas rely heavily on G-R Sound-measuring and Analyzing equipment. These instruments, of advanced design and highest reliability, are portable, battery operated, and completely self-contained for simple operation in practically any location. They include :

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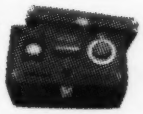
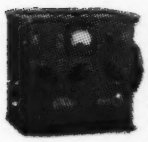
Type 1551-A Sound-Level Meter

. . . basic sound-measuring, tool for reading the sound-pressure level at its microphone in terms of the standard A.S.A. reference level.



Type 760-B Sound-Analyzer

. . . for narrow-band measurements of pitched sounds . . . best suited to measuring noise emitted by rotating, reciprocating or other cyclic mechanisms where prevalent frequency components are harmonically related to motor speed or other characteristic.



Type 1550-A Octave-Band Noise Analyzer

. . . for rapid, convenient broad-band analysis of "unpitched" sounds where the noise energy is widely distributed over the audio spectrum and is usually caused by shock excitation, impact or turbulence.

Type 1555-A Sound-Survey Meter

. . . low-cost, pocket-size sound-level meter for preliminary investigations prior to detailed study and analysis with above equipment.

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P 63

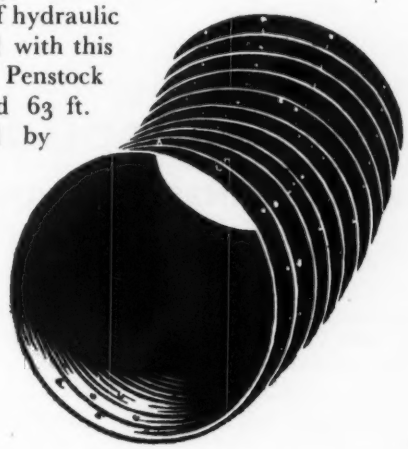
a

gateway

to the

future

HIRAKUD opens a gateway to the future for the people of India. The power generated and the irrigation waters released by the dam will bring life to new industrial areas, crops to barren soil and prosperity to the people. Texmaco, a pioneer in many fields of engineering and a leading manufacturer of hydraulic dam equipment, is proud to be associated with this mighty achievement of new India. Five Penstock Liners –25 ft. dia. x 7/8 inch thick and 63 ft. long—were designed and manufactured by Texmaco and erected at Hirakud.



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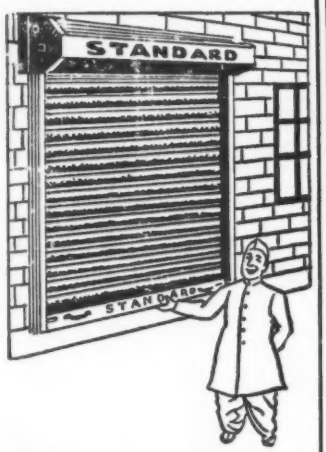
HIRAKUD DAM PROJECT

A STEP FORWARD :
TOWARDS PROGRESSIVE INDIA

"STANDARDS"

Contribution to the

PROJECT



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- **BHAKRA NANGAL.**
- **HIRAKUD DAM.**

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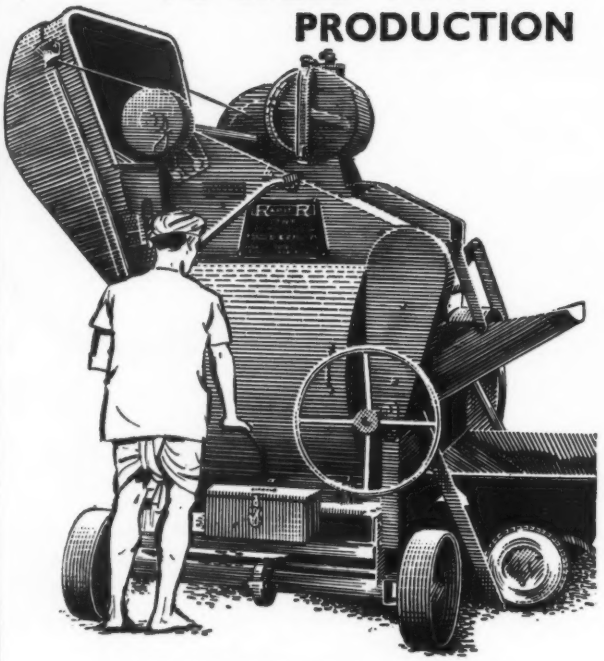

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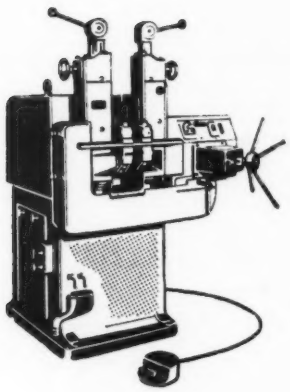

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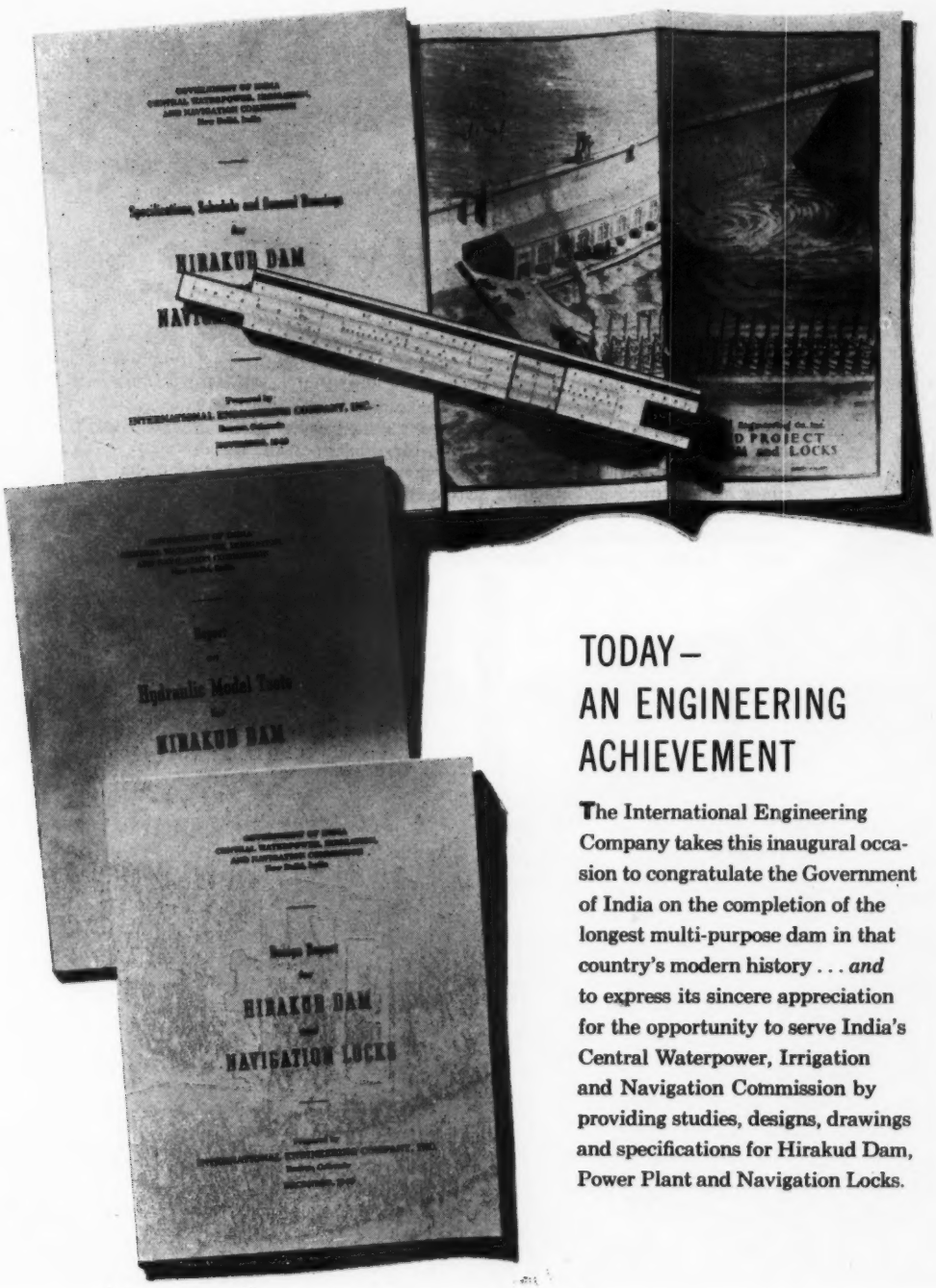

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Vol. VI — **HIRAKUD PROJECT NUMBER** — **No. 10**

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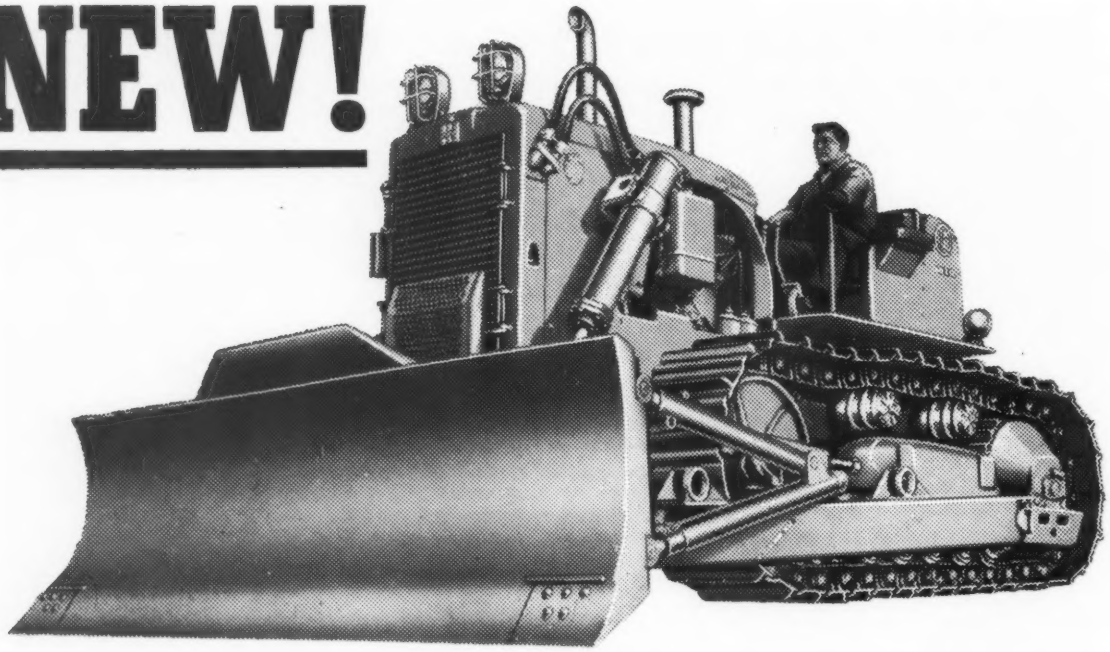

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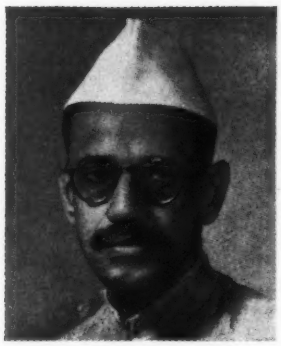


I am glad to note that on the occasion of the inaugural ceremony of the Hirakud Project, the Indian Journal of Power and River Valley Development is bringing out a special number on the Hirakud Dam project. The successful completion of this Project is a matter of very great significance to the nation. Substantial benefits in terms of additional irrigation, protection from floods and additional power (available for industrial and other purposes) will flow to the people of Orissa and the country. The fact that the Project has been constructed mainly by Indian engineers inspires confidence to the nation as a whole in its capacity to undertake many more projects of this magnitude. This dam will be a living example before our people how a river responsible for so much destruction of life and property in the past could be harnessed for the service of man. All this will influence their attitude favourably for adopting in this country modern technological and scientific advances. For all this the country should felicitate the engineers and workers who have participated in the construction of this huge project

The special issue presents all the facts about the Project and I am sure will be widely read with much interest.

G. L. NANDA

I am glad to know that the Indian Journal of Power and River Valley Development is bringing out a Special Number on the occasion of the opening ceremony of the Hirakud Dam. The Dam, whose construction has been made possible by the devoted work of the known and the unknown, who toiled day and night to realise the dream they had dreamt, is a standing testimony to the spirit of achievement that pervades the country. It is a symbol of India's striving to gather the scattered forces and harness them to the service of the common man. Turbulent waters of the Mahanadi, which till recently tread a path of recklessness, not unoften accompanied with devastation of colossal magnitude, have today been tamed and harnessed by the hand of man to serve their previous victims. The huge expanse of water which meets one's eye as far as it can travel, is truly the reservoir of Orissa's future prosperity. The project will revolutionise both agricultural and industrial life of the State.

On this memorable day of the inauguration of the Dam, I offer my congratulations to all, high and low, officers and men and others who worked to complete this magnificent national enterprise.

BHIMSEN SACHAR
GOVERNOR OF ORISSA

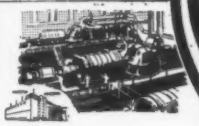
INTRODUCTION

Since the achievement of independence India has been a beehive of activity in all fields of constructive endeavour. The contrast with the preceding decades or even centuries is so striking that it appears as if the Indian Prometheus has been suddenly unbound, releasing in its magnificent splendour the mighty store of creative energy lying dormant for centuries in the womb of the Himalayas.

Today the very face of India is being changed even in a literal sense. From ancient times the mighty rivers like the Ganges, the Brahmaputra, the Indus, the Mahanadi, the Narbada, the Krishna, the Cauvery dominated and influenced the changing contours of the social scene of the Indian people. It is the people who used to adjust their lives and institutions and patterns of living to the spasmodic whims as well as to the calm placidity of these natural rivers. But today a new relationship is being shaped between the two. In the course of shaping and carrying out new patterns of life, the Indian people are redesigning the course of these mighty perennial life-giving waters. The River Valley Projects are the most outstanding landmarks in the economic reconstruction of India.

The Mahanadi which has been the cause of the formation of the landmass that is now known as Orissa is so intermixed with the life and history of the people of Orissa that it is difficult to treat it as something separate and distinct. The development of the Mahanadi river is synonymous with the progress and prosperity of Orissa people. The Hirakud Dam Project is a part of this integrated development programme. The mineral base of this region compares favourably with the richest bowls of earth in any part of the world. With the availability of power and irrigation from the great river, Orissa will now open its doors to the continuous progress and prosperity. One can confidently assert that in another two decades not only will the region be unrecognisable, but even its people will considerably change in their attitudes both towards their environment as well as to themselves. The earlier virility of the olden days will return in a new, modern context.

The following is the story of the beginning of that endeavour, albeit in technical language. The contributions compiled here provide a comprehensive view of the effort and insight that have gone into the making of the longest dam in the world. We dedicate it to the people of Orissa and India, so that it might inspire them to new heights of human endeavour which knows no end.



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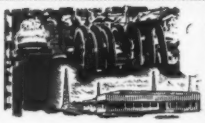

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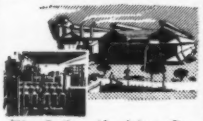

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A Gift to the Nation

By

M. S. THIRUMALE IYENGAR, B.E., M.E. (Hons), I.S.E., M.I.E, (Ind.)

Chief Engineer, Hirakud Dam Project

AUTHOR

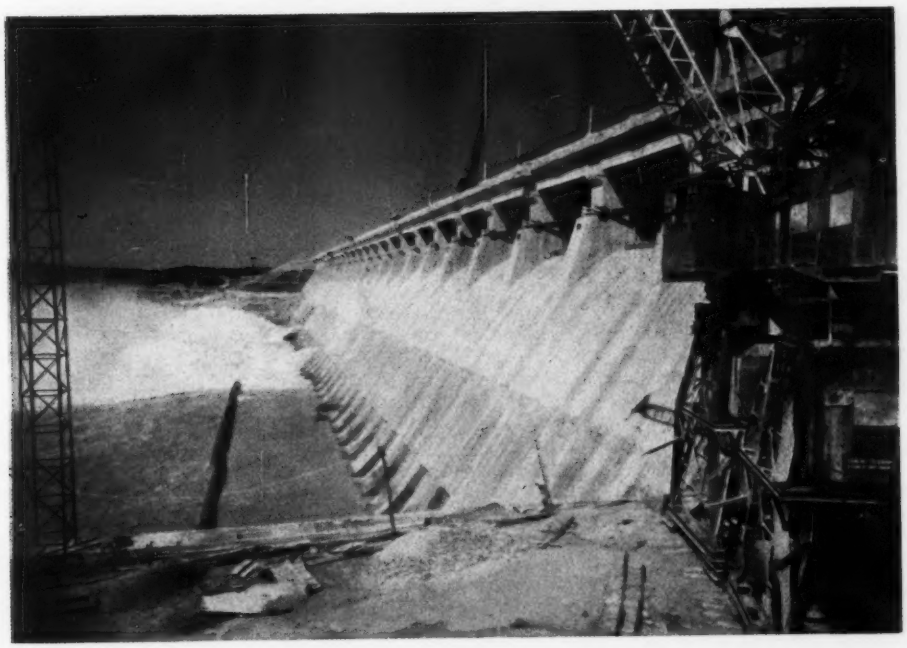
After years of patient, persevering hard work the engineers, specialists, technicians and workers are today making a gift to the people of Orissa and India in the form of the Hirakud Dam. It has been years of toil and sweat for thousands of our countrymen, even lives of some. But now that all this labour has reached the final shape of consummation and closes the chapter of flood, famine and devastation and opens a new chapter of industrialisation and modernisation, it is only proper that the story of this stupendous co-operative endeavour of man be recorded. The following pages are an attempt in this direction. The Chief Engineer has recorded in this contribution the salient features of the Project as well as the most important aspects of the experience gained in the course of its execution.

In olden times, man would appear to have been powerless against overflow of valleys of big rivers by floods resulting in destruction of homes and crops. Helped by wind sweeps, towns were obliterated and buried under silt and soil. The communities inhabiting the valleys moved elsewhere. But then there was plenty of land to occupy and other valleys to move on to, population being sparse. But with the lapse of time and rapid population growth, man learned to build dykes, dams, embankments and reservoirs making it gradually possible to protect the community from the destructive forces of rivers. The destructive force is now curbed and made to serve man for irrigation of lands and generation of power. And that is what we are doing to-day in many parts of the country.

One such in Orissa across the Mahanadi river, financed and executed by the Central Government on behalf of the State, is the Hirakud Project that will provide water and power for irrigation and industries all the year round. Land owners in the area commanded will benefit from the waters for a nominal investment on their part. And cheap power will be turned over to the various heavy industries like steel, aluminium and ferro-manganese through high voltage transmission lines and sub-stations. While power will also be made available to run the comparatively lighter industries like the textile mills, paper mills, sugar mills, tube mills and coal mines, intensive rural and urban electrification for small scale and cottage industries will receive high priority. Generating schedules have been worked out in accordance with power needs, available water and irrigation demands.

As the name indicates, the Hirakud Dam centres on and around the 'Hirakud Island' in the Mahanadi

Downstream view of the Left Spillway



Power Dam with Power House in the foreground

river. Here the river was flowing in four channels between two hills—three miles apart. The dam is essentially an earthen barrier across the main river with the requisite sections of concrete and masonry for the spillways, transitions, power penstock and turbine locations, flanked by earthen dykes nearly 13 miles long in five sections spanning the hills. Thus it is a 16-mile long dam, 200 ft. high at the deepest earth and masonry sections, and perhaps the longest dam in the world. The volume of earth that has gone into the main dam and dykes is by far the largest that has ever been put in any single dam in India. The earthwork at Hirakud exceeds the sum total of earth in Lower Bhavani, Gangapur, Maithon and Panchet Hill dams which are the four large earth dams built in India. Even when compared with the other earth dams in the world, Hirakud will rank in the first ten. It is also the largest reservoir in its class for combined power, irrigation and flood control potential. It stores nearly 7 million acre feet of water, spreads over 288 sq. miles, will have an installed capacity of power units that will give an annual production of over a thousand million kilowatt hours and will irrigate over two million acres of land.

Building such a huge water resources project is certainly not a simple task. Several years of planning, crossing hurdles and overcoming obstacles on many fronts are lost before you are rewarded with a tangible progress, peak construction and completion. The fact that the project is now completed is a credit to the sustained efforts of the vast army of engineers, builders and the Orissa State people. Several times the work seemed ready to progress only to be frustrated by some unforeseen or otherwise avoidable pitfalls and difficulties. Some of these are more interesting than the physical characteristics of the project and the construction programme, and these I prefer to pass over.

Studies of the Mahanadi river problems were carried out since several years prior to 1948. Finally this great project was launched in 1948 through the combined efforts of the Central Waterways, Irrigation and Navigation Commission then styled as "CWINC" and the Orissa State rulers at the time. While the "CWINC" assured the engineering feasibility, Orissa State rulers assured the future administrative and economic possibilities.

The designs and specifications for the main dam were drawn up by the Central Designs Organisation of the "CWINC" now styled as "CWPC" (Central Water and Power Commission). Some details of work on the main dam and all the designs and specifications for the works in the canal systems were drawn up by the Designs Organisation under the Project Administration at Hirakud itself.

The construction operations on this project in the beginning were planned with general bias in favour of comparatively intensive mechanised techniques. But technological consideration for intensive mechanised techniques assumes importance and significance only if the labour intensive techniques are technically unsound and unsuitable. The latter not being the case in regard to certain types of construction materials, particular attention was gradually paid to maximising the employment potential in order to meet the employment problem in the context of an economy with relative abundance of labour. Foreign purchases and aids in the shape of costly heavy machinery had, however, to be frittered away to some extent in large scale mechanised capital and operation costs. It must always be remembered and the fact should never be lost sight of that a machine-intensive technique involved displacement of labour which almost invariably reflected in 'strikes' and other labour troubles at once affecting the peaceful and speedy execution of the project. It has been argued that the construction of a dam of this type would be

a long and costly undertaking unless a great degree of machanisation was adopted. Nobody will deny that a certain degree of mechanisation is advisable to ensure rapid execution without upsetting the economic balance. Any search for means to achieve excessively rapid execution would result in too great a degree of mechanisation that will prove both wasteful and uneconomical. The use of a large mass of concrete as the construction material involves in heavy equipment for pouring concrete and the creation of heavy capacity aggregate and concrete handling plants, because of the considerable increase in the output required from the production installations and in the rate of pouring concrete. To reduce lost time and waiting periods, it also involves, in addition to equipment of great power and capacity, the provision of a more flexible and more rapid transportation services of a nature that is different with the nature of construction materials as for example "rubble in mortar," hand placed. There is the further fact that the operating conditions at the works for a concrete construction are peculiar. The greater the quantity of materials to be handled, the more important are the factors of regularity of construction and improved production. They involve in the use of certain techniques which form the basis of mass production methods. All these peculiar, unfamiliar and foregin features mean that we will have to use over-powered equipment, layout in parallel systems those parts of the installations which are most subject to breakdown, and instal highly mechanised and automatic machinery. The length of time spent in setting up such large and more complex installations is great, so that the reduction in construction time that an advanced degree of mechanisation was expected to bring about, would be greatly diminished.

Next the most disastrous feature in this pattern of affairs is the immobilisation of the expensive machinery due to two economically irremediable factors in the present circumstances.

Firstly, the machinery, being the imported stuff manufactured in distant countries, is entirely dependent for a trouble-free and efficient operation, on the stocking of a large and *excessive* quantity of spare parts that will assure a ready supply of any and every part both fast and slow moving, which means a huge lead investment and working costs that will throw economy to the winds. Experience has shown that the 20% or 25% spares recommended by the 'Agents' and obtained in advance with the machinery generally, nay, invariably have not helped us much. For want of spares, expensive machinery have been immobilised for considerable periods delaying execution of works and postponing the target dates of completion resulting in the cost mounting up with the pay-rolls of the idle operation personnel, the interest on investment and the huge losses on account of the delayed accrual of benefits from the project. The expenses of transportation, of assembly and dismantling, the cost of machine repair and maintenance shops and the presence of numerous specialists—all weigh heavily on the cost. However efficient the maintenance and operation units may be, immobilisation for long periods due to want of spare parts cannot be avoided. While Indian engineers must gain the best advantage from the new possibilities offered by the evolution in the mechanical equipment for building large dams, they should not lose sight of their responsibility to the country to avoid all unnecessary heavy expenses that will upset the economic balance. Of course, mechanisation is not altogether undesirable. Much depends on the construction material. Where excavating and hauling very large quantities of earth from long distances are involved, use of mechanical equipment

Out Door Switchyard at Hirakud

for digging, loading, hauling and compacting would be definitely advisable though it means spending enormous amounts on spare equipments not to speak spare parts themselves. Inspite of efficient maintenance, workshop facilities for repairs, overhaul and even manufacture of some parts, some of the costly machinery have consumed 200% spare part cost. Sickness percentage is near 40% under the best of circumstances if we do not commission the spare *whole* machines to replace some of the sick ones. Inspite of the enomrous costs that these work out to, very large earth dams like the Hirakud, that involved the placing of 25 million cubic yards or about 68 crores of cubic feet of compacted earth in the structure, had to use large scale heavy earth-moving and other auxiliary equipment for rapid execution. Where stone is the construction material, the pattern and outlook will certainly be different. Experience at Tungabhadra and Hirakud definitely point to the adoption of rubble-in-mortar as a more effective and more economical proposition.

It is, therefore, only by a judicious application of available means for the kind of construction and the scale of work involved, that we will ensure both economy and speed of execution. On the Hirakud work, the traditional labour-intensive techniques were put on a more scientific and efficient basis to meet the challenge of the machine intensive techniques in the construction of certain parts of the structure, which resulted not only in economy but also in providing maximum employment to the skilled and unskilled labour. One such change is the substitution of rubble stone masonry to concrete in the Power Dam and transitions. In this connection I cannot resist the temptation to say something about the unnecessary controversy that was raised in regard to rubble-stone-masonry for dams. Our engineers went to America and saw the dazzling, awe-inspiring mechanisation that is at the bottom of all the so-called "technical know-how" and came back to tell the story. The type of all-out intensive mechanisation using concrete as construction material is perhaps most suitable for a dam like the Bhakra—high and narrow gorge location. But it has blinded some of us and has blurred our vision. We now turn our eyes away from the excellent traditional rubble construction adopted in our ancient irrigation works that have been the cynosure of the eyes of the world and that have stood the test of ages. Some of our engineers say that they are no good for our dams but that the rubble crushed into bits in crushers, batched and mixed in batching plants costing 25 to 30% more is superior to the solid stone structure. This point of view is urged on the ground of time, economy and speed in construction schedules. As regards speed of construction, the period of execution under the worst circumstances for rubble-stone-masonry and under the best circumstances for crushed rubble-stone-concrete will show very little disparity because the initial two to three years to set up installation for concreting machinery must be set off against the slower rate of construction that is made much of in the use of rubble masonry.

Then there is the other point of time economy that is oft repeated viz., that the accrual of benefits would be delayed. A dispassionate examination of the question would show this point has no base at all. The 100% development either in irrigation or power is never attained over-night. It is planned for a gradual development and for that pace of development full height of dam is not necessary. And masonry construction, even if it prolongs completion by one or two years, would still keep pace to enable the programme of development envisaged being kept up. The storage at the lower levels would be sufficient to meet the demands of both power and irrigation.

There is also a great deal of fuss made about the quality of the construction material in the whole body of the dam. Although it is essential, for safety of the dam, to give it a perfect homogeneity, expert opinion has it that it is really not so much necessary to use material of exceptional quality for the whole body. A certain thickness of the upstream face is made more rich with cement and well controlled, and behind this, the net work of galleries is put in. This arrangement allows the use of a less rich and even less carefully controlled material for the largest part of the dam. Of course, it is different with an arch dam. Here high stresses develop which have to be resisted by material of high quality in every part of it. I will leave the philosophy of masonry dams at that with just the remark that the Hirakud Dam would not have been completed a year earlier but for the substitution of rubble stone masonry in the Power Dam section.

An idea of the vast labour employment potential that this project possessed could be had from the fact that at the times of peak construction during the last three years, the total number of labour employed was well over 30,000. This consisted of the various types of artisans — masons, stone dressers, fitters, riggers, carpenters and several other categories of skilled workers apart from an army of unskilled men and women labourers. A harmonious and co-ordinated balance was kept up between the mechanised and human labour operations throughout. During the 'peak' periods we had an awe-inspiring panorama of construction operations. On the intensive mechanised front a vast array and number of machines roamed roaring like some huge pre-historic monsters. Gigantic power shovels dug, lifted and disgorged soil into waiting dumpers. Gigantic loaders cut and belt-conveyed the soil to pour into the dumpers moving alongside. Scraperloaders, with their bonnets thrust forward from the body like the head of a rhino and with their 'bowl' like bodies on immense rubber-tyred wheels, filled their bellies with earth as they scraped the same with blades underneath, and sped away roaring to spit out the earth on the dam at the intended place. Huge dozers dozed and fleet of sheeps-foot rollers rolled to compact the earth —all a combined non-stop operation. And then you had the huge batching and mixing plants linked on one side with a crushing and conveyor unit and on the delivery side, a fleet of diesel locos hauling the concrete filled buckets to the site for the lifting and placing cranes to handle. The batching and mixing plants of 12 cyds. and 8 cyds. capacities were, however, found to be the middle links in an unbalanced chain and so could not be worked to maximum capacities. Nevertheless they worked though proving a little uneconomical. It only proved that where intensive mechanised techniques are employed, a very careful initial planning is called for.

Radial Crest Gates on the Left Spillway

All these soulless mechanical automatons produced but fleeting impressions of their performance. The ever lasting impression was, however, the most grand and soul-stirring sight of the army of workers, skilled and unskilled, men and women several thousands strong drawn from all parts of India from Cape Comorin to the Himalayas, who were the real builders of the magnificent edifice toiling night and day with single-minded purpose and devotion to duty. Verily that was an unforgettable sight to see, admire and wonder and the memory of which will never fade.

Some of the peculiar and noteworthy features incorporated in this dam deserve special mention. There is a battery of 64 gated bed level sluices of size 12′-0″×20′-4″ each in a spillway length of 2125′ operated from a gallery of size 11′-0″×23′-0″ in the belly of the concerete structure. This is the biggest spill and sluiceway that has been constructed in any dam in the world. This operation gallery and the battery of that size sluices are said to be the largest of their kind in the world. These sluices can pass down nearly nine lakhs of cusecs under full reservoir conditions. Aswan Dam in Egypt has a large number of low level sluices. But they are much smaller in size and operate under a varying low head of 22′ to 45′ only. The Hirakud bed level sluices operate under a maximum head of 120′. The seven power penstock pipes embedded in the masonry section of the dam is of 25′ diameter each. Some of the huge bulk-head gates of size 41′-4″×24′-6″ at the entrance to these sluices were manufactured at the Hirakud workshops. Not only these, the workshop manufactured six sets of draft tube steel stoplog gates of size 25′-6″×18′-1″. It also fabricated some high voltage transmission line towers. The erection of trestle bridge on the rear face of the spillway for carrying four huge six ton cranes, the track and concrete hauling equipments, the operation and maintenence thereof requiring the greatest skill, courage and self-confidence, were all the work of our young Indian engineers assisted by skilled artisans—all of Indian origin. Cranes were dismantled and reerected by them. Possessing initiative and resourcefulness, these boys worked like a team and have done a magnificent job creditable to themselves and the engineering profession in the country. Mechanised operations, foundation grouting and other construction techniques that are ordinarily believed to be a foreign technical expert's and technician's job, have all been with great confidence and courage, successfully tackled by our Indian engineers. It can truly be said that this huge construction at Hirakud has trained and turned out experts in the line who can be trusted to successfully carry out such and other difficult jobs elsewhere with confidence and ease. On the electrical side the Indian engineers and technicians have tackled the jobs normally believed to be difficult and foreign in the field of operation. Hundreds of miles of high voltage transmission lines have been erected departmentally. In the erection of huge switchyard and power units and in every phase of construction in this field, our men have shown worth and courage.

Orissa possessed immense water wealth in her rivers, particularly the Mahanadi, the Brahmani and the Baitarani. There are large areas of fertile cultivable land, big deposits of key minerals and a large population of intelligent and industrious people. By integrating the development of her natural resources and harnessing her man-power, Orissa can become industrially and economically a great State. There are possibilities of development of a deep sea port at the mouth of the Mahanadi or the Brahmani. During the thirties the Ukraine in Soviet Russia was a backward agrarian State like Orissa. On completion of the Dneiper dam it became one of the most prosperous industrial and agricultural

States producing coal, minerals, etc., and a manufacturer of heavy equipment. The completion of Hirakud will similarly transform Sambalpur and Orissa into one of the most prosperous agricultural and industrial areas in the country. The signs of such development are already visible on the horizon. A modern aluminium smelter plant is taking shape just at the foot of the giant dam. Foundation is being laid for the huge blast furnaces for the Rourkela steel plant. A ferro-manganese production industry is taking shape under Hirakud Power Wing. Expansion of the cement plant at Rajgangpur is under way and plans are through for the establishment of paper mills at Chowdwar and expansion of production at Brijrajnagar. Similar activity can be witnessed all over the State.

Some people thought that the Hirakud Project submerged the diamond mines that existed here in some unknown past. They will realise very soon that the completion of the project and the creation of the Hirakud lake opens up the real diamond mine, rich in its variety and benefits, producing more food, turning the giant wheels of industry, and mitigating the devastation and destruction of floods that have been the root cause of famine and drudgery in this backward State.

Hirakud opens up the chapter of Valley Development in Orissa. Similar schemes on the Brahmani Baitarani, Salandi and other rivers are on the anvil. Hirakud marks the beginning of an era of higher standards of living for the common man in Orissa, freed from floods, famines, want, drudgery and disease. It is a gift to the Nation—a gift by the millions of workers and engineers, those that left their hearth and home to work for the benefit of their fellowmen elsewhere, and those that gave up their lives in this service and did not live to see and enjoy the fruits of their labours.

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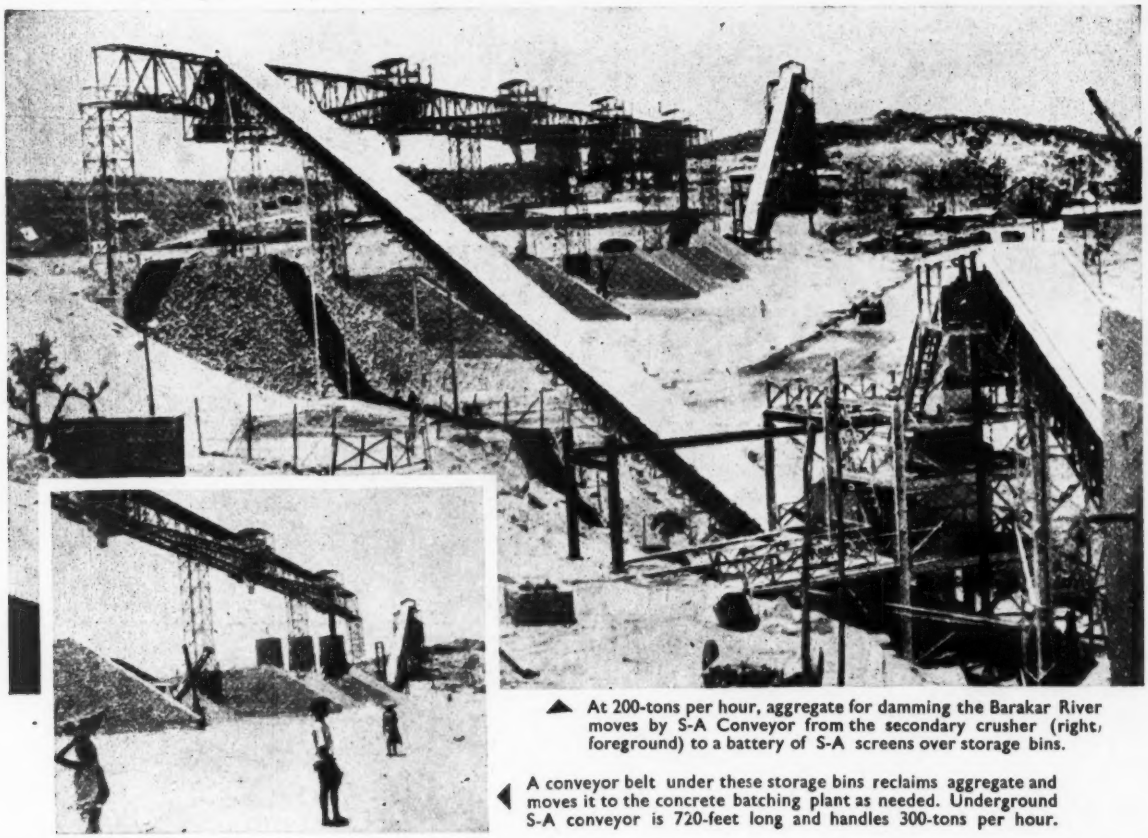

▲ At 200-tons per hour, aggregate for damming the Barakar River moves by S-A Conveyor from the secondary crusher (right, foreground) to a battery of S-A screens over storage bins.

◀ A conveyor belt under these storage bins reclaims aggregate and moves it to the concrete batching plant as needed. Underground S-A conveyor is 720-feet long and handles 300-tons per hour.

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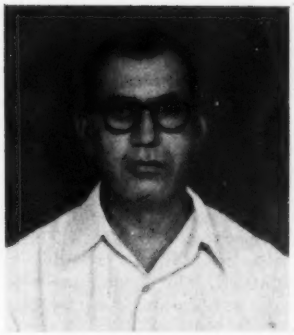
Construction Features of Hirakud Dam

By

A. R. CHELLANI, B.E.

Superintending Engineer
In charge of the Main Dam, Hirakud Dam Project



AUTHOR

The central feature of the Hirakud Dam Project is the Dam itself. It is possibly the longest dam in the world. Mr. Chellani, the author of this contribution, has been in charge of the Dam construction from the start to finish and as such, he is the most competent person who can explain the construction features with authority.—Ed.

The Hirakud Dam is the biggest single dam constructed so far in the country. Also it is the longest in the world to-day. It consists of 15748 feet long earth, masonry and concrete dam flanked by earthen dykes 32,275 feet in length in 5 gaps spanning hillocks on the left, and 35,500 feet on the right in one stretch.

The Main Dam is constructed in 5 sections :—

(1) Masonry Power Dam—gravity type ..	948′
(2) Right Concrete Spillway with Masonry Transitions. ..	1180′
(3) Earth Dam of zoned filled type in the island ..	7540′
(4) Left Spillway concrete portion with Masonry Transitions. ..	1640′
(5) Earth Dam of zoned filled type on the left side. ..	4440′

The maximum height of the Dam in masonry portion is 200′ and that in the earth portion 195′.

In the Power Dam there are 7 penstocks of 23′ to 25′ diameter which are the largest in Asia and in the Far East.

In the Power House there are at present 4 generating sets, 2 English units of capacity of 37,500 k.W. each; and 2 German units of capacity of 24,000 k.W. each. There is provision for three 37,500 k.W. units for future extentions.

In the Spillway there are 64 sluices controlled by vertical slide gates, 24 in Right Spillway and 40 in the Left Spillway of size 12′×20′-4″, which is the biggest in Asia. On the Left Spillway there are 21 crest bays, and on the Right Spillway 13, each 51′ wide with 20′ high Tainter type radial gates.

The quantity of concrete and masonry in the Dam including Power House is 391 lakh cft.

The Earth Dam involved 44.15 crores cft. of earth work which is a huge quantity and that too with a long lead varying from 1 mile to 7 miles. In volume this is the first biggest in Asia and the 4th biggest in the world.

The quantities of the main items of work and the materials used in the Main Dam are as under :

Excavation for foundation of Concrete-Masonry Dam in common soil.	64.19 lakhs cft.
Excavation for foundation of Concrete-Masonry Dam in common rock.	161.33 ,, ,,
Quantity of concrete, mass, R.C.C. face	232.02 ,, ,,
Quantity of concrete, masonry face.	158.47 ,, ,,
Quantity of cement used.	2,50,000 Tons
—do— steel in reinforcement.	11,000 ,,
—do— of excavation of cutoff trench—common	69.73 lakhs. cft.
—do— —do— rock	14.15 ,,
—do—of filter materials sand and shingle.	147.30 ,,
—do— Rock fill.	158.50 ,,
—do— Rip-rap	166.80 ,,

From the above figures the enormity of the work can easily be gauged. Added to these was the difficult and complicated nature of work in foundations due to peculiar geological strata, heavy sub soil water troubles and vagaries of weather which allows only 6 to 7 months in a year for work.

At the site of the Dam, the river Mahanadi had 3 channels, thus forming 2 islands in between, called Hirakud and Kolarikud. The middle channe has been permanently closed with earthen dam. On the left channel comes the Left Spillway and on the right channel the Right spillway and Power Dam

Diversion of River during Construction

3½ miles above, the river has 2 channels. This helped in the diversion of water during the different phases of construction.

For working in the left channel, a coffer dam was built across the left channel shown at point 'A' in plate II, every year from 1951-52 to 1953-54 till the sluices were completed. Gap 'B' between left channel and middle channel was also being closed. To do work in the right channel, a coffer dam was built in the right channel at point 'C' in the years 1952-53 and 1953-54, and at point 'D' in the years 1954-55 and 1955-56 till the Dam was completed. In the year 1951-52 left channel was kept closed and winter supply passed through middle channel and deepest stream in the right channel. In the years 1952-53

and 1953-54, both left and right channels were closed and the winter supply passed through middle channel. In the year 1954-55 right channel was closed and winter supply passed through Left Spillway. In this year Earthen Dam was built across the middle channel about 100′ in height, a huge task done in one season. In the year 1955-56, a coffer dam was built in the right channel and winter supply passed through the Left Spillway.

A coffer dam was built with earth and rockfill as shown in the sketch Plate III. Stream was closed with rockfill. As rockfill proceeded, earth work followed. The closing gap was closed with crates filled with rubble and tied by thick wire ropes. The discharge through the closing gap on the closing day used to be of the order of 10,000 cusecs. Each coffer dam every year involved a quantity of 13 lakhs cft. of earth work and 1.5 lakhs cft. of rockfill. It used to take a month to stop the flow and then further time in strengthening it.

The Power Dam and Power House portion was completely encircled with a protective bund from the year 1950-51 upto the year 1954-55 and kept above flood level to carry out the work during monsoon too.

Design of the Dam and Profile

It is designed as a straight gravity dam. The over-flow portion of the Dam has got a vertical face, crest at elevation 610 with parabolic curve, and rear face with 0.7 to 1 slope. Sill level of the sluices is at elevation 510. Over the crest comes the bridge with piers upto elevation 634 and road level at elevation 642. At the rear of the sluices there is 44′ wide bucket to form a water jump and dissipate the energy due to very high velosity through the sluices. The non-over-flow portion of the Dam has a front batter of 0.1 to 1 upto elevation 550 and above that the face is vertical. The rear of Dam has a slope of 0.7 to 1 with constant width of 25′ above elevation 609.29.

CONCRETE MASONRY DAM

Construction of the Structure : The non-over-flow portion of the Dam including PowerDam and training walls is built in granite stone masonry. About 5′ depth of concrete is laid in foundations under the masonry. All the openings in the structure are built in reinforced cement concrete 5′ thick in penstock openings and 3′ in all other cases. The copping is done in concrete. The over-flow portion is built in plain concrete and bucket crest, piers and all openings in reinforced cement concrete.

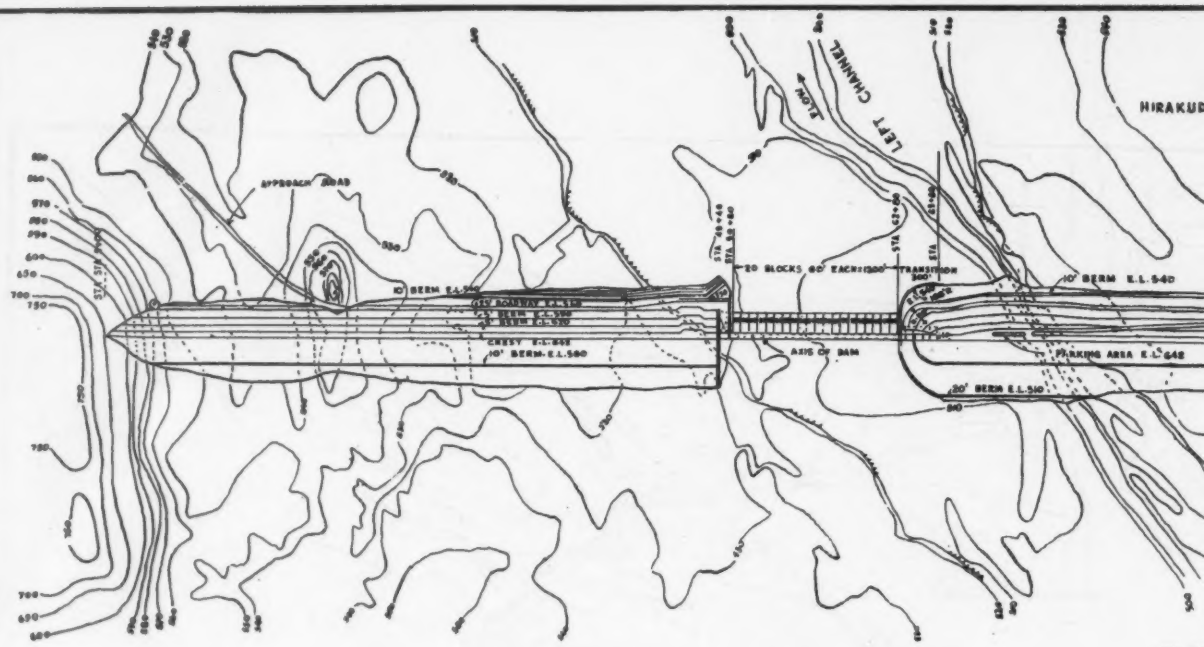
Excavation for Foundation

The total quantity of excavation for foundation in the entire dam including Power House was 225.52 lakhs cft. out of which 161.33 lakhs cft. was excavation in rock. The depth of excavation in Left Spillway varied from 10 ft. to 30 ft., in Rght Spillway form 20 ft. to 45 ft., in Power Dam from 35 ft. to 73 ft. and in Power House from 65 ft. to 71 ft.

The method adopted for this huge quantity of excavation work was a homogeneous and economic blending of men an machinery. Air compressors and Jack Hammers were used for drilling, gelegnite and special geletine, water proof fuse-electric and ordinary detonators were used for blasting. Liquid oxygen was tried but it was not successful due to sub soil water trouble and too much of leakage in transit.

The removal of muck was done by manual labour, shovel and dumpers. In the Spillway, most of the muck was thrown by manual labour on the down stream which used to be washed away by the floods in monsoon. In Power Dam and Power House portion, the spoil was removed by shovels and dumpers.

The geological strata varied considerably. Intensive cores were taken to know the details at each and every place fully and each portion was tackled and treated accordingly. The foundation rock was mostly granite and in several reaches, arkose, epidiorite and granite impregnated with quartz. There were many fault zones in the foundations, which were excavated either to deep level or special treatment had to be done, considering economy, the nature and extent of the fault. In the Left Spillway, there were shattered and crushed zones in blocks 5, 7, 8, 12, 13, 14, 16, 20 and 26 where the excavation was taken very deep till satisfactory rock was met. In blocks 12 and 13 of the downstream left side flank wall, chloride schist was met which, when fresh, was as hard as granite, but when left overnight under water, crumbled like clay. This sort of rock extended in a depth of 15′ and had to be removed till good hard and sound rock was met. In blocks 14 and 20, there was good hard granite rock 10′ in depth over a very thin layer of disintegrated strata which had to be cleaned and washed by air water jets by drilling holes and grouted. There was crushed zone in blocks 30, 31 and 32 where the excavation was taken to E.L. 480 i.e., 30′ below river bed level. In blocks 33, 34 and 35 there were local fissures and joints. Excavation there was taken to deeper levels till good rock was met with and joints were grouted. In blocks 36 and 37 the hard rock sloped very steeply from the middle of the Dam section. The steep portions were benched and dowels were put in for proper bunding. In blocks 38 and 39 there was a wide zone of crushed epidiorite between granite rock running from upstream of the Dam to the downstream, detailed cores were taken and this band was excavated to E.L. 473 i.e., 37′ feet below bed level where fissured but hard rock was met with. The entire area was grouted. Some of the downstream holes were interconnected with the fissures of blocks 40 and 41. A number of holes were drilled in the fault zone along blocks 40 and 41 also and grouted. In all the slopig surfaces dowels were put in before concreting. In blocks 43 to 47 in the upstream portion good granite was met with at an average elevation of 488 i.e., 22 feet below bed level but in the rest of the portion the excavation had to be taken further 18′ lower to get suitable foundations after taking detailed cores. In block 45, a fault zone ran through its centre, which had to be excavated till hard rock was met with. In block 47, in the upstream 30′ width, hard granite was met with at 17′ below bed level, after that it dipped vartically by 25′. On this slope dowels of 2′ dia M. S. bars were put in and reinforcement of N. G. rails put in as shown in the sketch. In block 48 a fault zone parallel to the axis of the Dam at 50′ downstream of the axis was met with. This was dug to hard rock and reinforcement of old N. G. rails was provided spanning the fault zones. Detailed cores were taken and the excavation had to be taken down to elevation 468 i.e., 42′ below bed level when good rock was met with. The foundation of block 53 was badly



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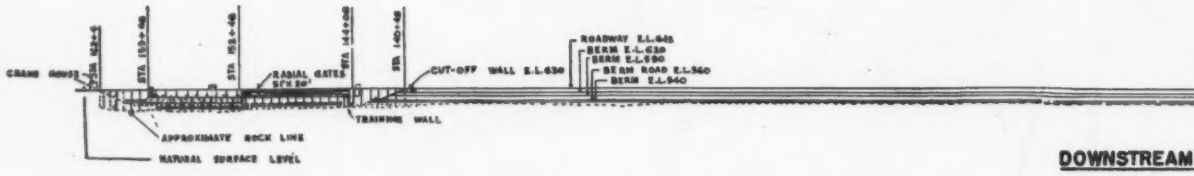
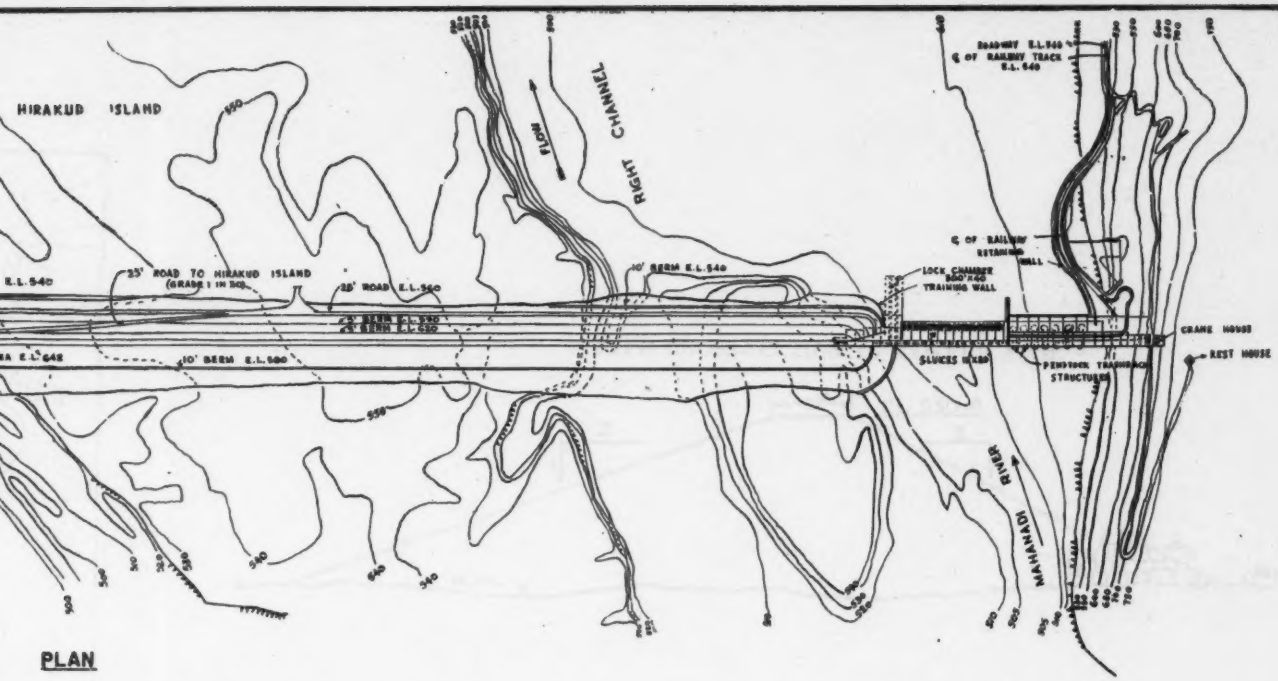
UPSTREAM



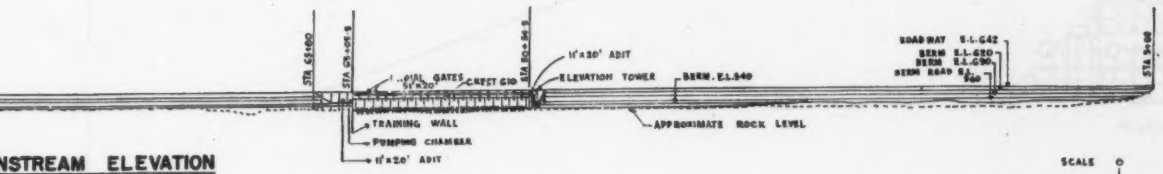
DOWNSTREAM

FIG 2



PLAN

TREAM ELEVATION



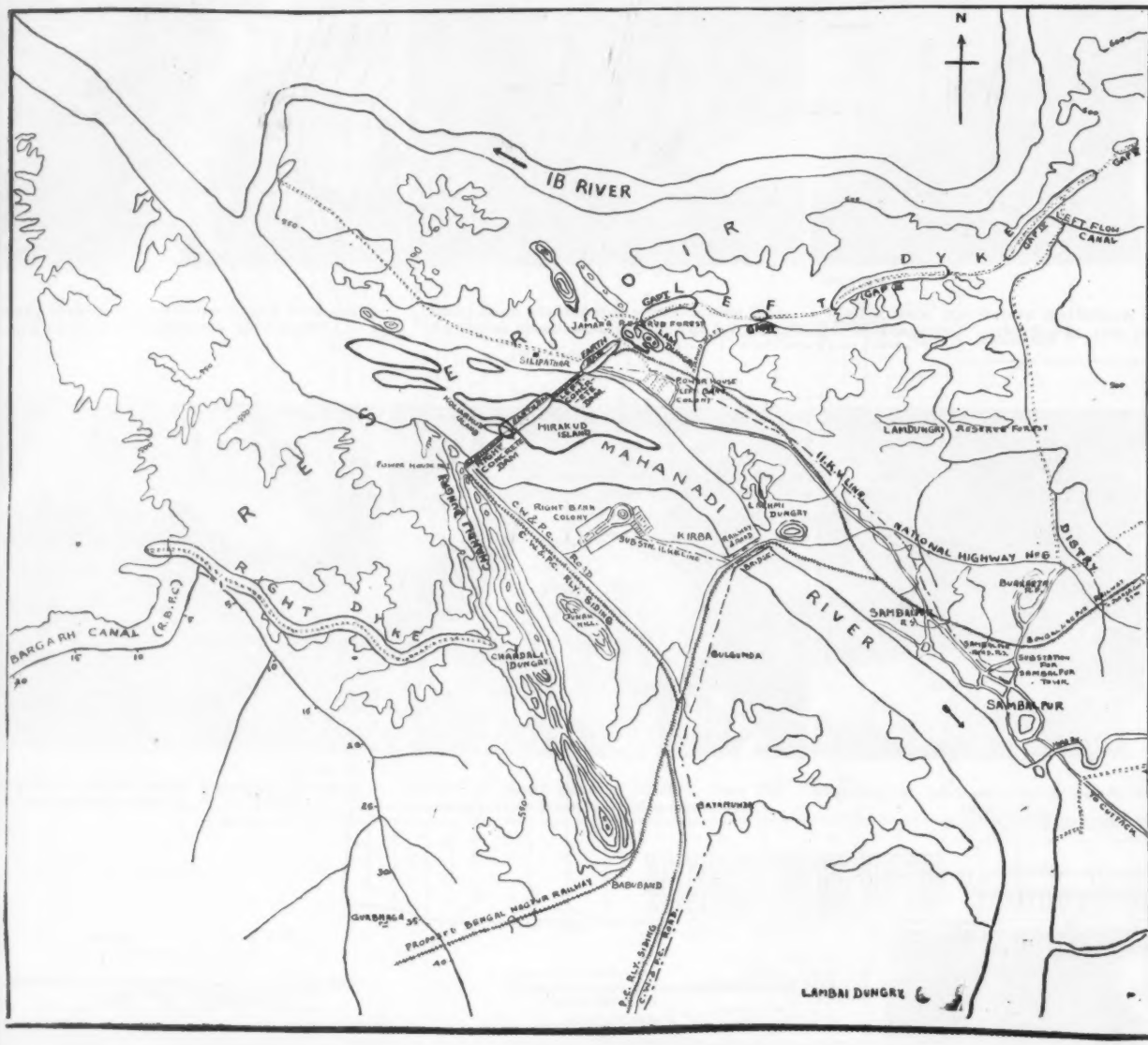
NSTREAM ELEVATION

SCALE 0 500 1000 1500 FEET

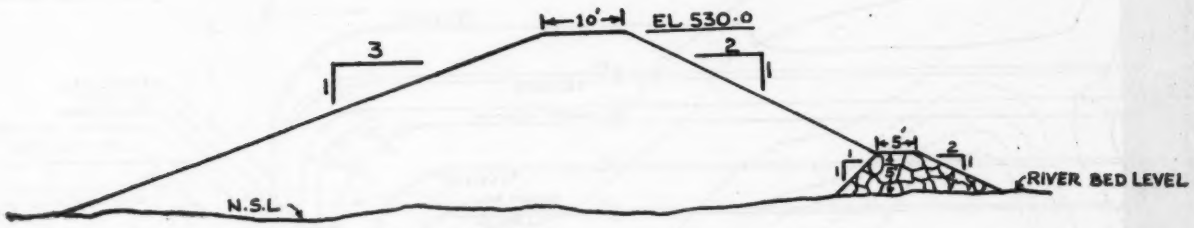
GOVERNMENT OF INDIA
MINISTRY OF IRRIGATION AND POWER

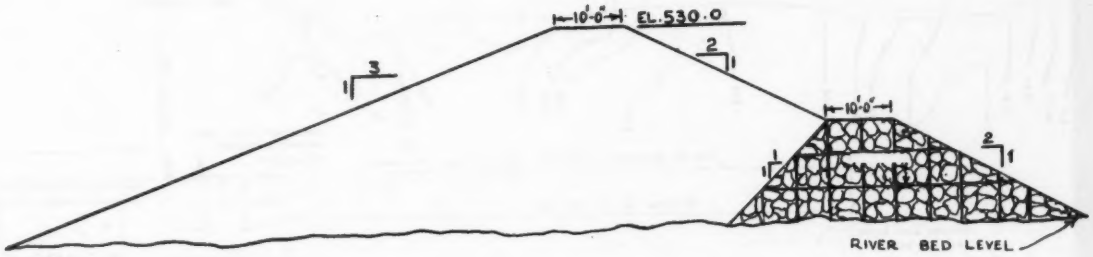
HIRAKUD DAM
MAIN DAM
GENERAL PLAN & ELEVATION

AUGUST, 1954.


N
IB RIVER
LEFT DYKE
GATE
GATE
GAT

TYPE CROSS-SECTION OF COFFER DAM





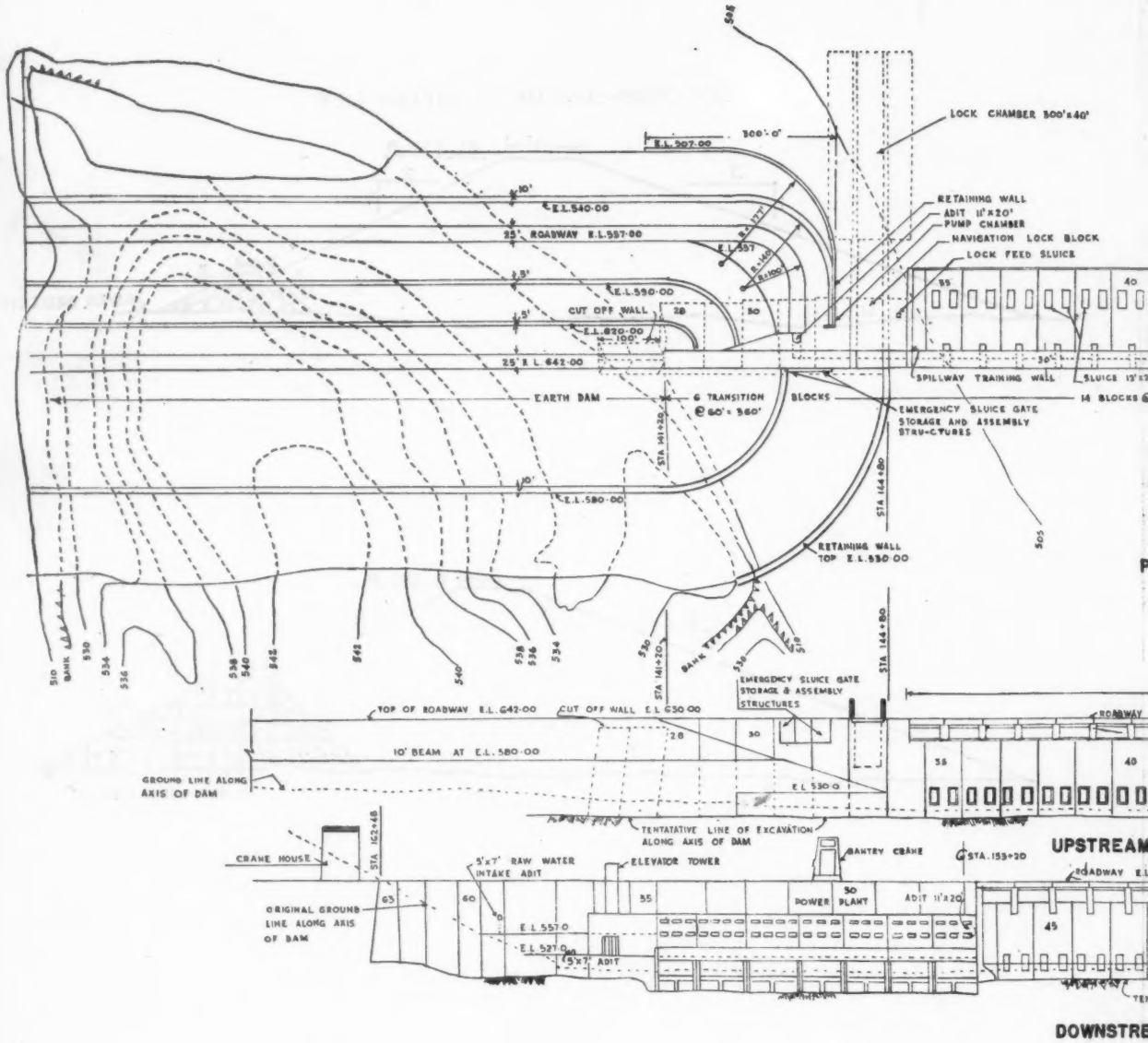
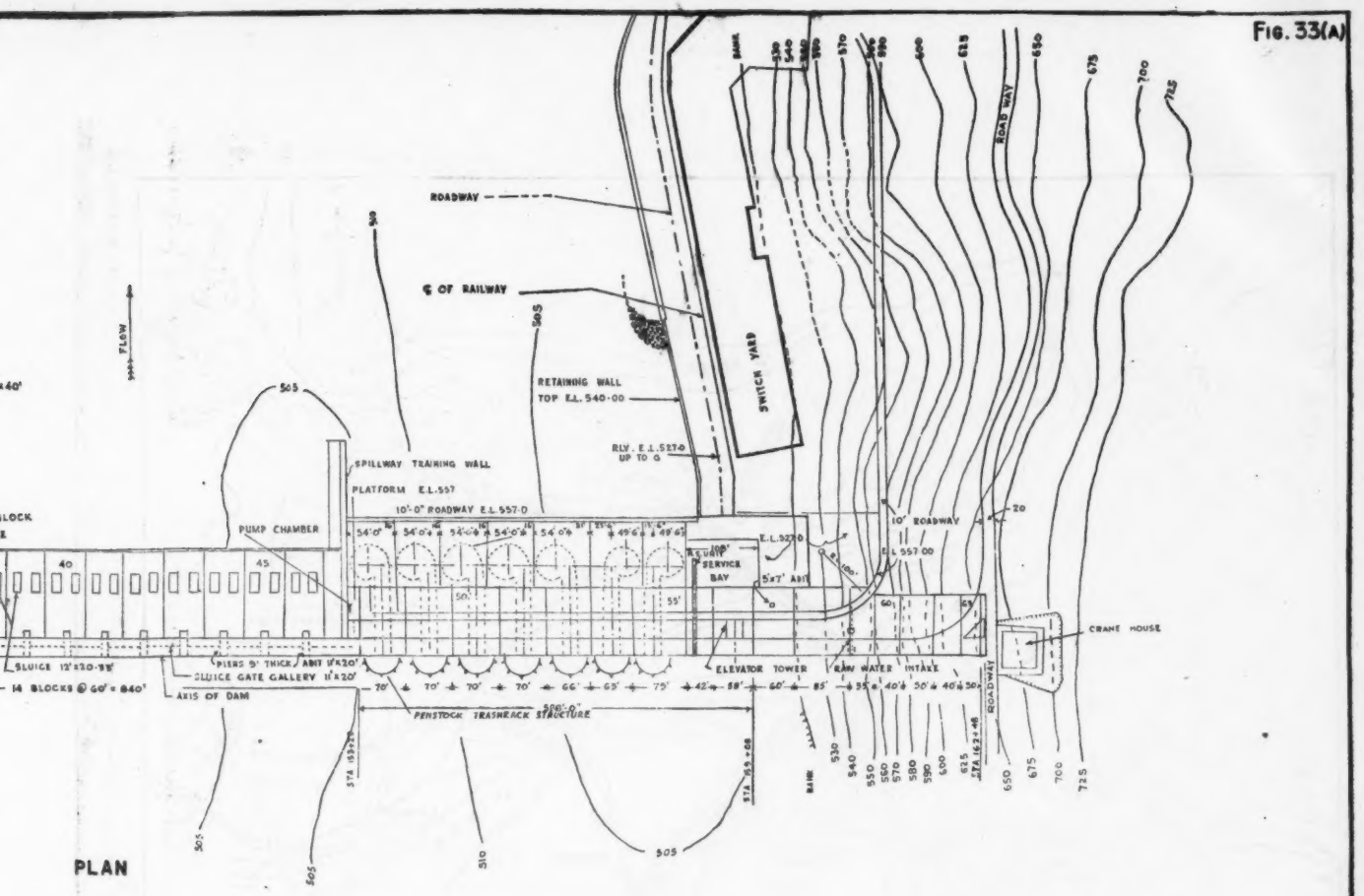
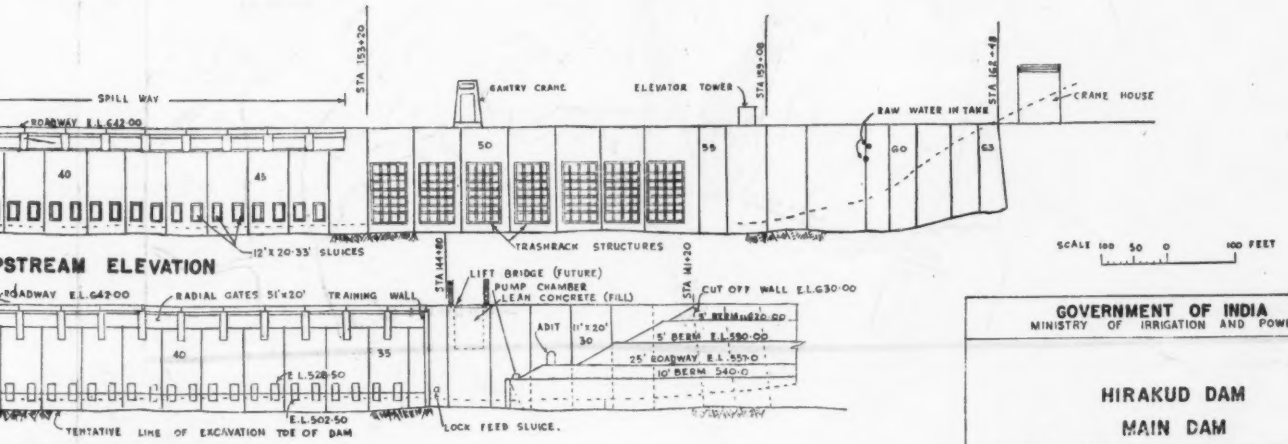

LOCK CHAMBER 300'x40'
300'-0"
E.L. 567.00
RETAINING WALL
ADIT 11'X20'
PUMP CHAMBER
NAVIGATION LOCK BLOCK
LOCK FEED SLUICE
E.L. 540.00
25' ROADWAY E.L. 557.00
E.L. 590.00
CUT OFF WALL
E.L. 620.00
25' E.L. 642.00
EARTH DAM
6 TRANSITION
@ 60'= 360'
BLOCKS
SPILLWAY TRAINING WALL
EMERGENCY SLUICE GATE
STORAGE AND ASSEMBLY
STRUCTURES
STA 141+30
STA 144+80
E.L. 580.00
RETAINING WALL
TOP E.L. 630.00
TOP OF ROADWAY E.L. 642.00
CUT OFF WALL E.L. 630.00
10' BEAM AT E.L. 580.00
GROUND LINE ALONG
AXIS OF DAM
E.L. 530.0
TENTATATIVE LINE OF EXCAVATION
ALONG AXIS OF DAM
CRANE HOUSE
STA 162+48
5'x7' RAW WATER
INTAKE ADIT
ELEVATOR TOWER
GANTRY CRANE
STA. 153+20
UPSTREAM
ORIGINAL GROUND
LINE ALONG AXIS
OF DAM
E.L. 557.0
E.L. 527.0
5'x7' ADIT
POWER
PLANT
ADIT 11'X20'
DOWNSTRE

FIG. 33(A)



PLAN



PSTREAM ELEVATION

OWNSTREAM ELEVATION

GOVERNMENT OF INDIA
MINISTRY OF IRRIGATION AND POWER

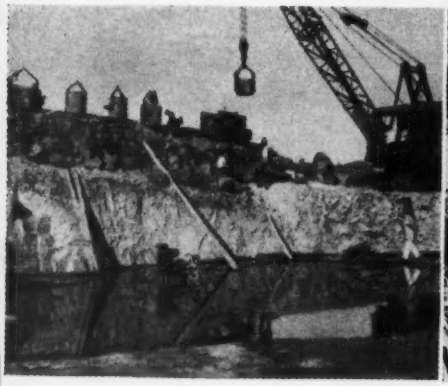
HIRAKUD DAM
MAIN DAM
RIGHT CHANNEL PLAN & ELEVATION

AUGUST, 1954.

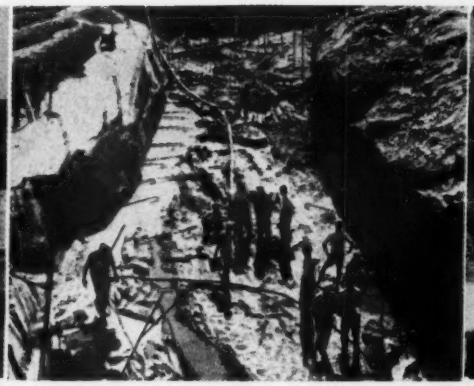
Closing of the final gap in the Coffer Dam with crates he'd in position by wire ropes.

Coffer Dam withholding water during 1954. The Coffer Dam was overtoped on 8/7/1954.

Coffer Dam just before the breach on 5/6/56. There was early floods this year.



Excavated muck being removed by crane and transported by N. G. Locos.



Details of shear zone in block 5. Note the anchor rods from the sides of the shaft.

Cleaning of rock pockets in block 14, prior to concreting.

Condulets provided at steep rocky slope for contact grouting.

A view showing the fissure in block 37.

Crushed zone in blocks 38 and 39.

Excavation in block 45.

Grouted rock joints at the contraction joint of blocks 48 and 49. These are exposed when the weathered rock was removed in block 49.

Foundation in block 49.

Closer view of foundation in block 49.

Downstream face of Excavation in block 49.

Excavation in the crushed zone in block 54 at the upstream end.

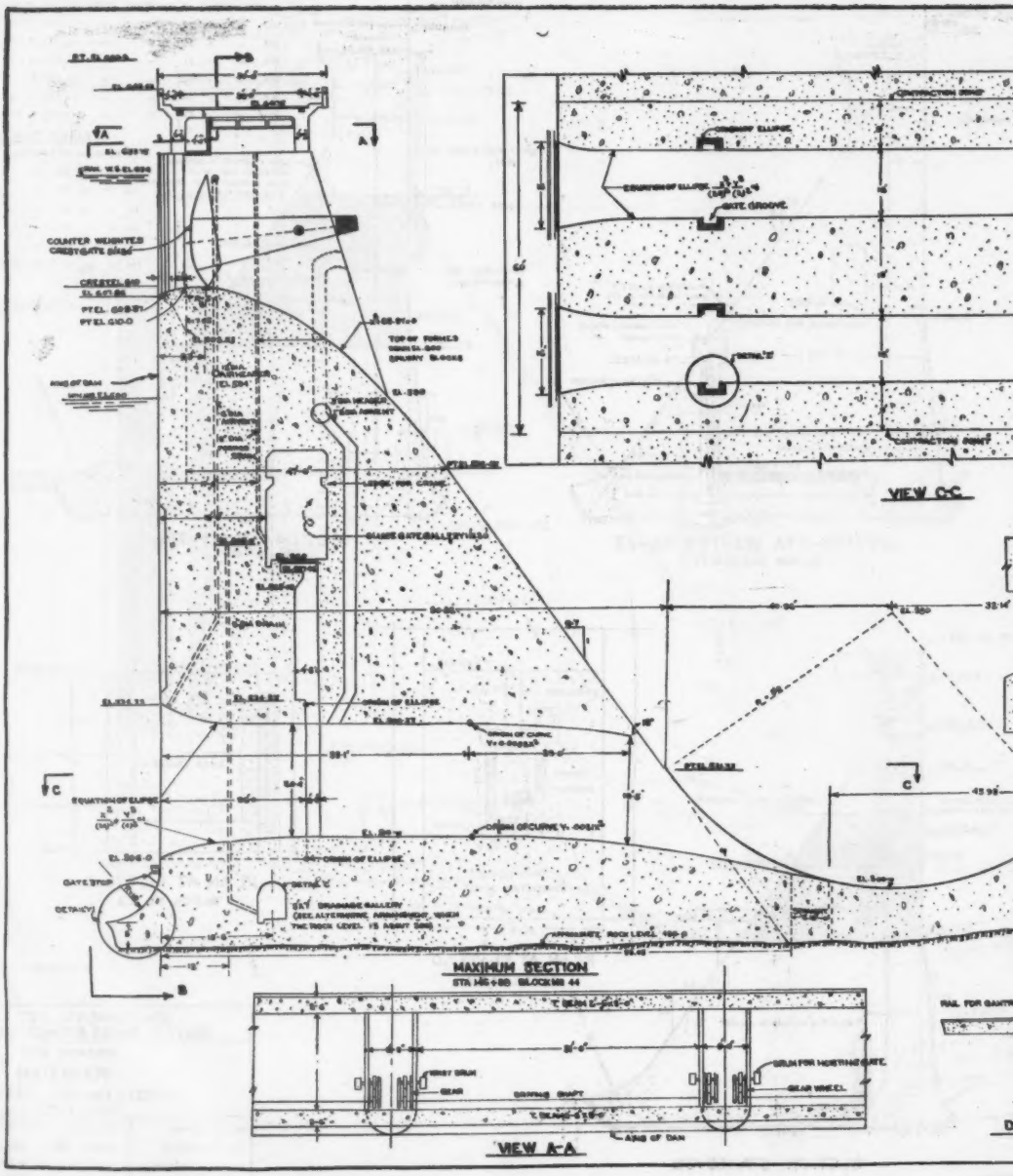
View of the slate and granite thrust plane in block 52.

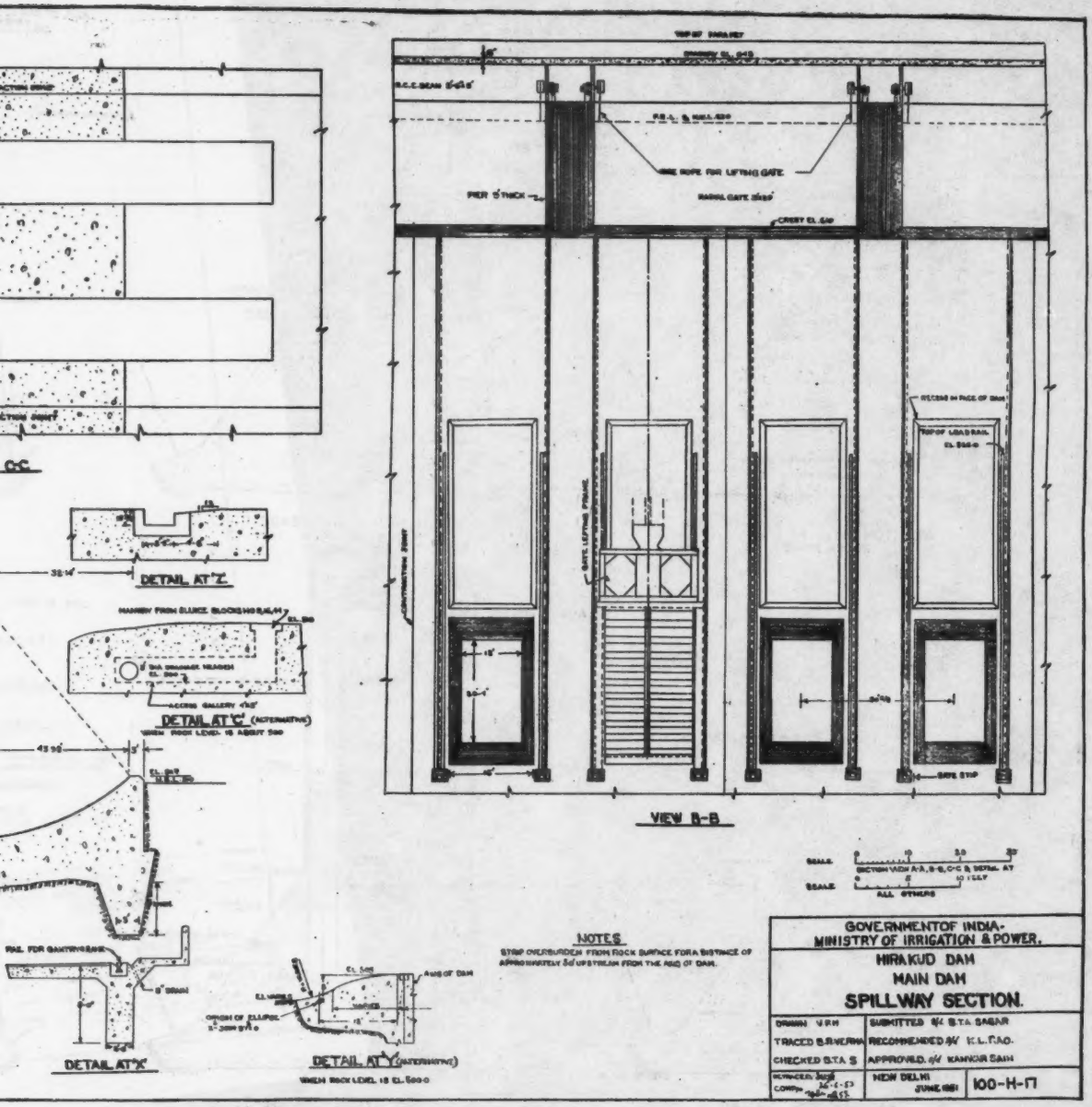
Upstream face excavation in block 54.

the

49.

block


VIEW C-C
MAXIMUM SECTION
VIEW A-A



NOTES

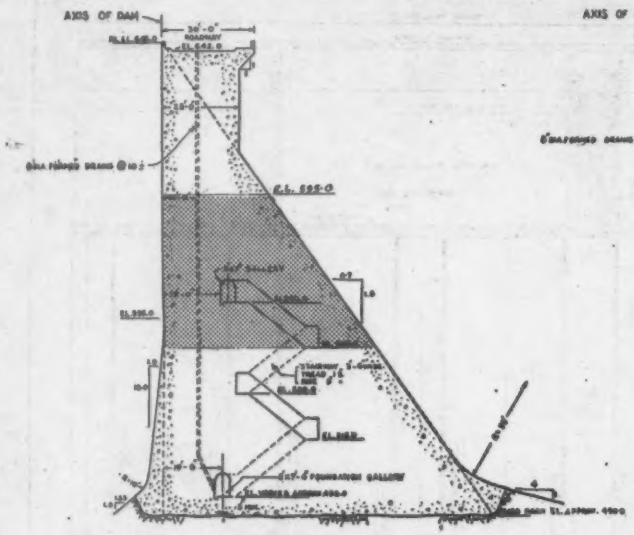
STRIP OVERBURDEN FROM ROCK SURFACE FOR A DISTANCE OF APPROXIMATELY 50' UPSTREAM FROM THE AXIS OF DAM.

GOVERNMENT OF INDIA-
MINISTRY OF IRRIGATION & POWER.

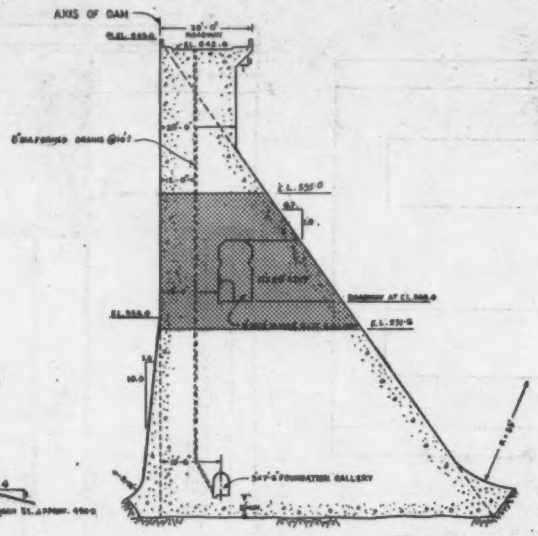
HIRAKUD DAM
MAIN DAM
SPILLWAY SECTION.

DRAWN V.R.M	SUBMITTED S/d S.T.A. SAGAR
TRACED S.R.VERMA	RECOMMENDED S/d K.L.T.A.O.
CHECKED S.T.A.S	APPROVED. S/d KANWAR SAIN
SCHEDULED DATE 26-4-53 COMPLN. DATE 30-6-53	NEW DELHI JUNE 1951

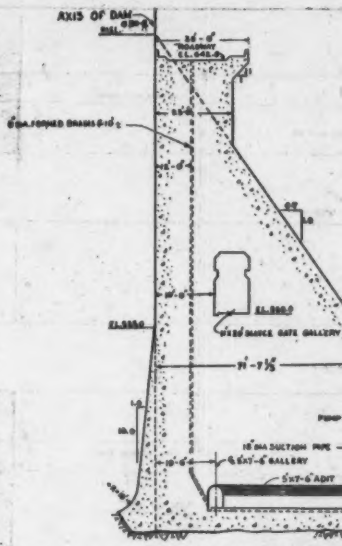
100-H-17



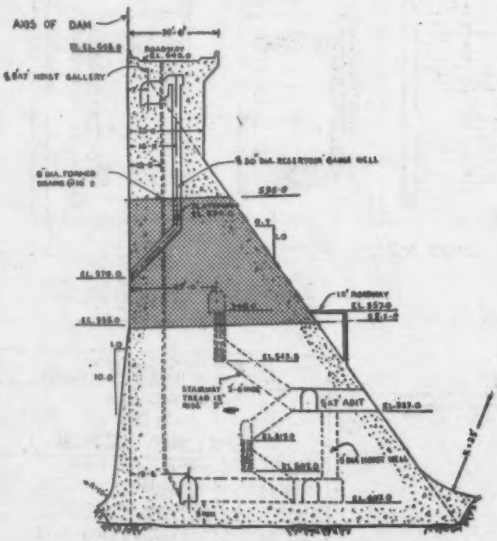
SECTION-STA.142+08
BLOCK NO.30



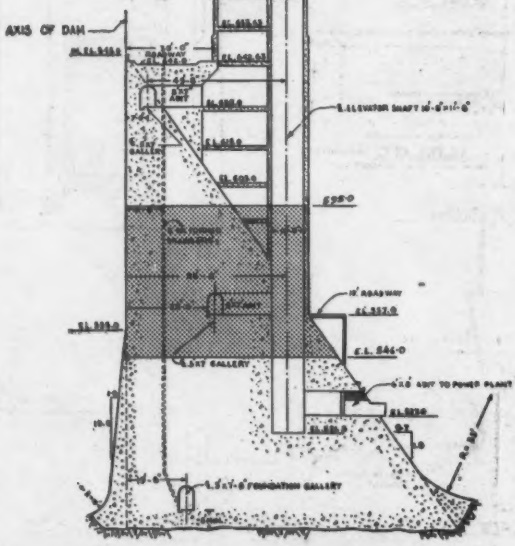
SECTION-STA.142+56
BLOCK NO. 31



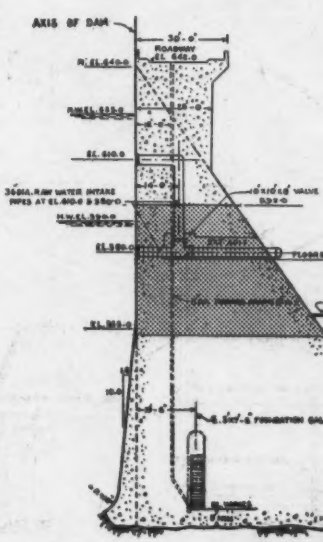
SECTION-STA. 14
BLOCK NO



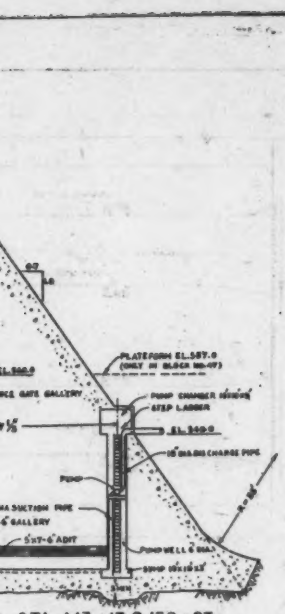
SECTION-STA. 159+38
BLOCK NO. 57



SECTION-STA.158+78
BLOCK NO.56



SECTION-STA
BLOCK NO



-STA. 143+13 & 152+23
BLOCK NOS 32 & 47

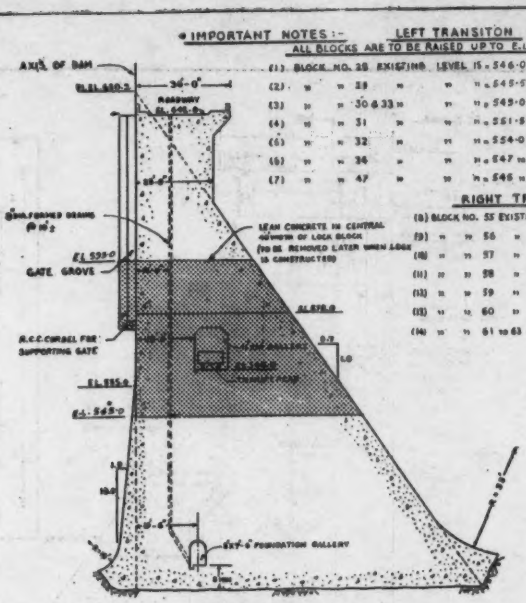
• IMPORTANT NOTES :- ALL BLOCKS ARE TO BE RAISED UP TO E.L. 595·0 BY 15-6-55

LEFT TRANSITON

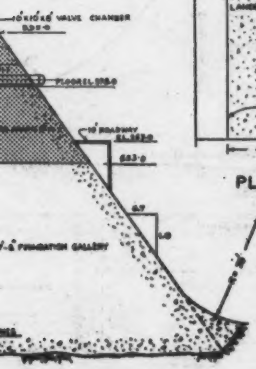
(1) BLOCK NO. 28 EXISTING LEVEL IS = 546·0 (M)
(2) " " 29 " " " = 545·5 (")
(3) " " 30 & 33 " " " = 545·0 (")
(4) " " 31 " " " = 551·5 (")
(5) " " 32 " " " = 554·0 (")
(6) " " 34 " " " = 547 " 529·0 (AV)
(7) " " 47 " " " = 546 " 511·0 (")

RIGHT TRANSITION

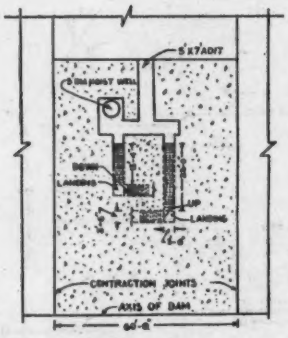
(8) BLOCK NO. 55 EXISTING LEVEL IS = 518·0
(9) " " 56 " " " = 546·0
(10) " " 57 " " " = 554·0
(11) " " 58 " " " = 560·0
(12) " " 59 " " " = 553·0
(13) " " 60 " " " = 540·0
(14) " " 61 to 63 NOT RAISED AT ALL.



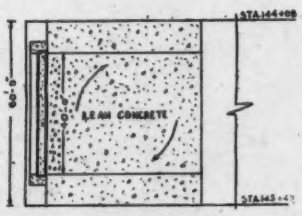
SECTION-STA.143+76
BLOCK 33



TION -STA. 160+58
BLOCK NO. 59



PLAN AT EL. 527.0
BLOCK NO. 57



PLAN AT EL. 578.0
BLOCK NO 33

GOVERNMENT OF INDIA
CENTRAL WATER & POWER COMMISSION

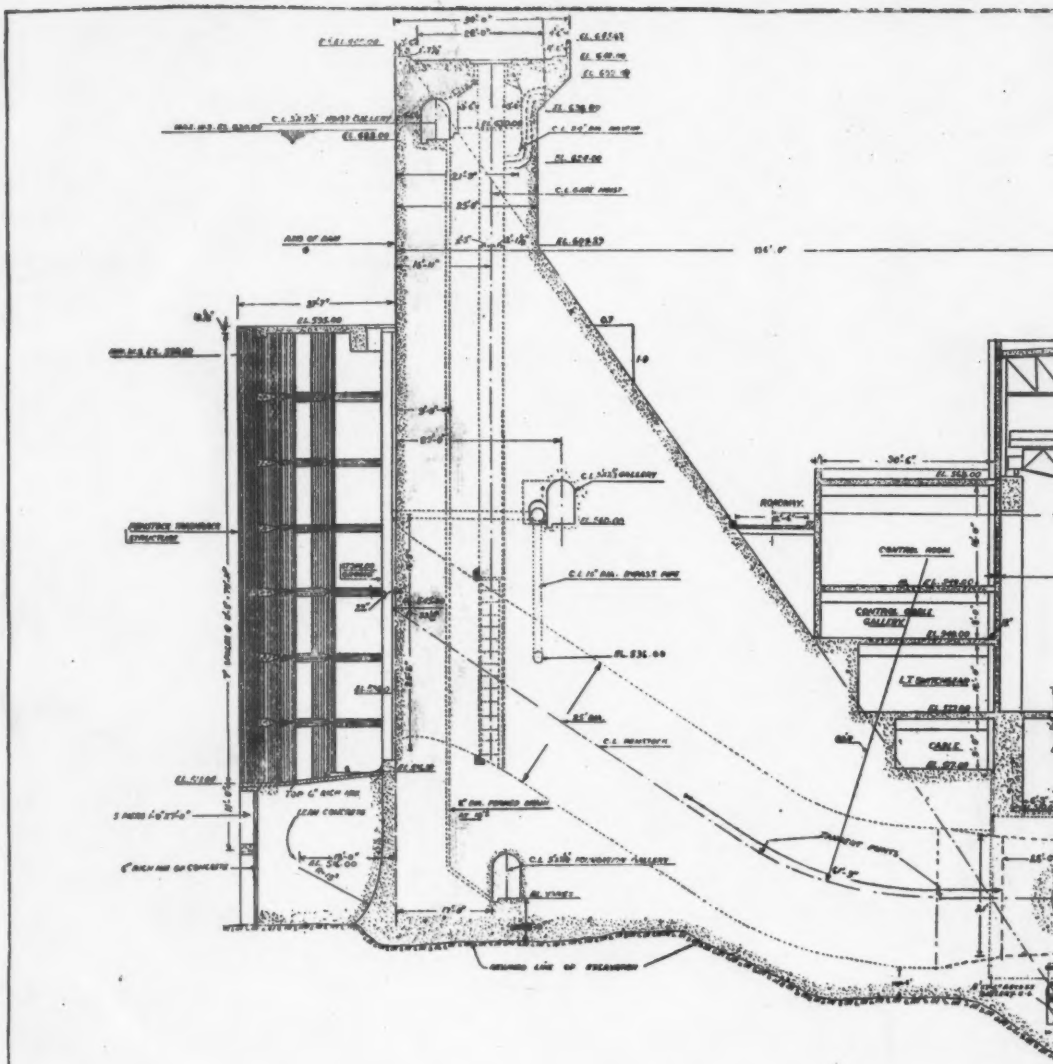
HIRAKUD DAM

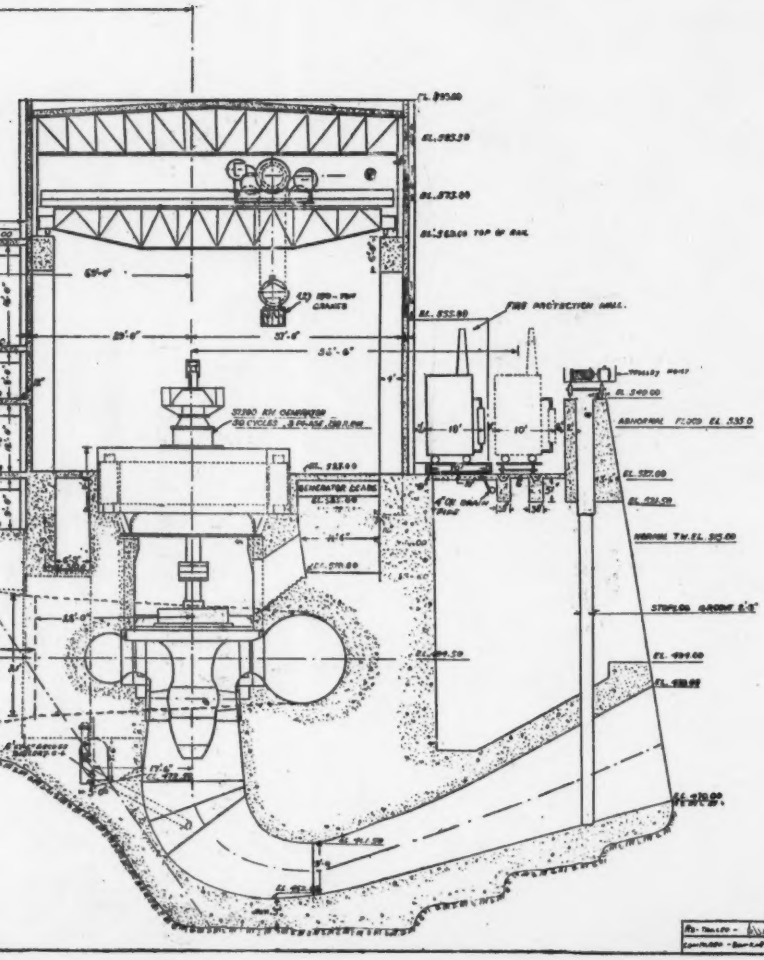
MAIN DAM

MISCELLANEOUS SECTIONS
(RIGHT CHANNEL)

DRAWN S/SHRI	SUBMITTED S/D/ K.C. THOMAS.
TRACED S/SHRI LOK	RECOMMENDED S/D/ K.L. RAO.
CHECKED S/S/ B.S.N.	APPROVED S/D/ KANWAR SAIN 19·5·51
RE-TRACED BY, N.C. GHAL 15-9-51. CHECKED BY	NEW DELHI MAY-1951

100-H-35(A)





SCALE 0 20 40 FEET

GOVERNMENT OF INDIA
CENTRAL WATER & POWER COMMISSION

HIRAKUD DAM

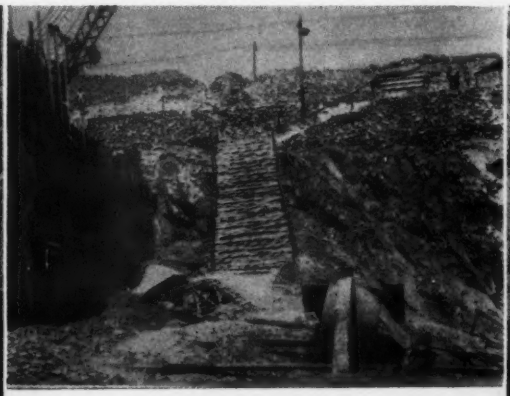
MAIN DAM

MAXIMUM POWER DAM SECTION.

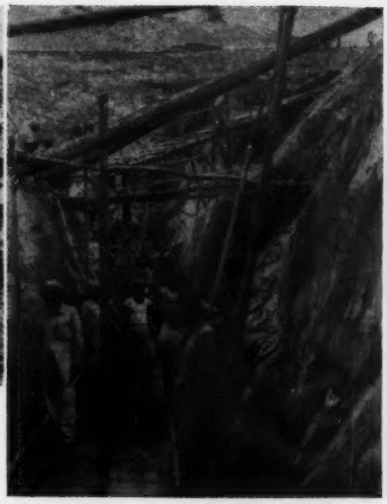
Drawn w/f T.C.T.	Submitted - J.K. Bandy
Traced - J.M.G.	Recommended - K.L. Rao
Checked - P.C. Maj.	Approved - [illegible] 23.8.51

100-H-33

Excavation in the shaft across the clay gorge in block 54.

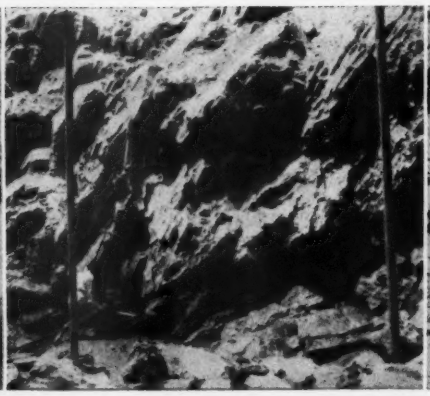


Upstream face and part of foundation of block 55.



Another view of excavation in the shaft across the clay gorge in block 54.

Cleaning, operation in the weathered seam in block 58.



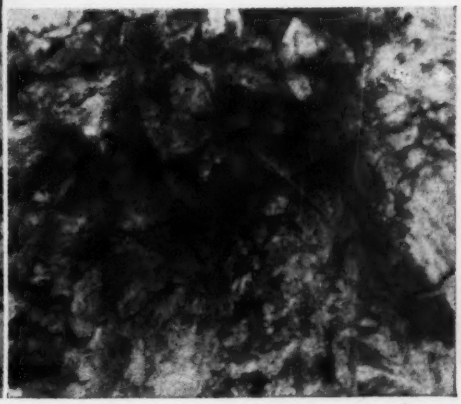
Rock wedge in block 59 upstream portion.

Upstream face of excavation in blocks 59 and 60.

Upstream face of excavation in blocks 60 and 61.

Upstream face of excavation in blocks 61 and 62.

Foundation of Power House Unit No. 1.



Foundation of Power House unit 1.

Drilling with Wagon Drill for consolidation grouting.

Washing of holes. See water gushing out of an interconnected hole.

Water gushing out from an interconnected hole.

Washing of holes with blow pipe of compressed air and water.

The grouting plant in operation.

The header connections.

A closer view of the header connections.

Final clean up of foundations. The seams and loose and disintegrated rock being removed with point-edged hammer and wire brushes. Note the battery of mixers which were used for concreting in the foundation during 51-52 season.

crushed and excavation had to be taken to elevation 465 i.e., 50′ below river bed. In block 54, foundation rock, even at elevation 462 i.e., 53′ below bed level was found to be crushed with local areas of soft rock. Core holes were drilled and it was found that there was no improvement even upto elevation 410 i.e., 105′ below river bed level. Pressure test was taken on this crushed rock and settlement was observed with a load of 50 T/sft.

There was a completely crushed zone near the junction of blocks 54 and 55, right from upstream to downstream of the Dam. At the upstream this soft area was excavated to elevation 432 i.e., 83′ below river bed level and in the rest of the zone trench was dug upto 452 i.e., 10′ below the general foundation level of the block and concreted in order to provided a cut of the block. All the local soft pockets were excavated deeper. Reinforcement of N. G. rails at 2′ centres in both the directions was provided at the base of the foundations.

In blocks 55 to 57 foundation rock consisted mostly of softer stones such as arkose, silt stone and slates. The entire foundation area was grouted. Blocks 58 to 63 are in the slope of the hill. The foundations in these blocks were made in rising steps. Foundation rock was the same as described for blocks 55 to 57. The entire area was benched and contraction joints of the block were located at the vertical faces of the steps. The rock in the foundation of the hill slope block was very much jointed and the blasting had no effect. It was a job to excavated foundations. After drilling the holes with wagon drills, the holes were filled with cement water upto the top. After about 2 to 3 hours the holes were reformed by inserting drill rods. The holes were afterwards charged and blasted, which gave very good results

The foundations of Power Units I and 2 at the required level of 447 was found to be soft and crushed. The excavation was taken to elevation 444 and heavy reinforcement at the base was provided

Clearing of the Final Bed Layer

After finishing the excavation by blasting to the acceptable foundations on sound rock and approved strata, all the loose portions were removed by wedging and barring. Care was taken that no portion of rock with any crack in it was left and the rock below was preserved in the soundest condition.

Dewatering of foundations

There was heavy subsoil water seepage from sides and bed, the nature of rock being peculiar and the foundations being very deep, it was a colossal job to keep the founations dry for working by keeping heavy pumps at main places and a number of smaller pumps feeding them, working all-round the clock. Local shallow pits were dewatered by pneumatic sump pumps. In the Power Dam and Power House work was carried out during monsoon also by dewatering with heavy pumps. There was one Russian pump with 5000 gm discharge, four 110 H.P. electric pumps, two Diesel pumps with 2000 gm. capacity and a number of 60 H.P., 30 H.P., 20 H.P., 10 H.P., and 5 H.P. pumps.

Foundation Treatment

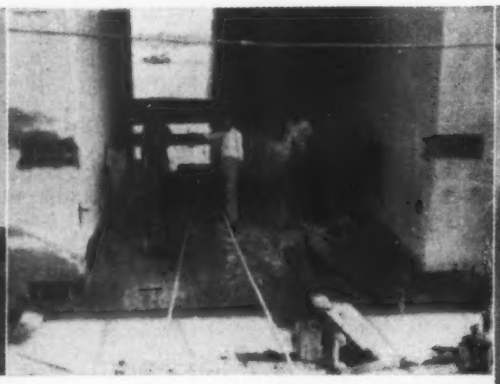
For consolidation of foundations, making them water-tight and improving the stability of foundation rock, low pressure grouting was done.

As already mentioned, the rock of this region are composed mostly of granitic gneiss intersected by large number of joints, seams faults, fissures, shear, and crushed zones. In some locations it was schist, slate and shale. During the process of excavation detailed investigation of defective zones was done by taking out cores with diamond drill. After careful study, method of treating each zone was decided on its merits. 4 rows of low pressure holes from $1\frac{3}{4}''$ to $2\frac{3}{4}''$ diameter were drilled with wagon drill 30′ deep at 20′ centres in position, the first row located along the axis. Where there were fissures, faults and crushed zones, holes were drilled at closer intervals upto 5′ even. In blocks with faulty zones, area of foundations grouted depended on the area covered by such faulty zones. In some cases, entire area of the block was grouted. In such cases, spacing, depth, inclination, order of drilling and grouting and the pressure used were decided from the nature of rock and geological strata

Procedure of Grouting

The holes were throughly washed with blow pipe by air and water pressure. Inter-connections were watched. If there were seams and joints, they were also washed. The washing was continued till the seams were completely washed out and the effluent from the inter-connected holes was clean. Then, each hole was taken for grouting. Before grouting it was tested by pumping water under the maximum allowable pressure, in this case 70 P.S.I., for minimum period of half an hour. Any leaks occuring on the surface of rock foundations were caulked with lead, wood or jute pieces. The amount of water taken by the hole indicated the water cement ratio to be used. Grouting was then started. The grout mix. varied from 12 : 1 to $\frac{1}{2}$: 1 by volume. The grout intitially injected was lean mix. If grout leaked through the adjacent holes, they were capped with plugs. Grouting was done at a maximum pressure of 75 P.S.I. and continued upto refusal. Inter-connected holes were then taken one after the other. At places of fissures, faults or crushed zones, inclined holes were drilled at intervals of 10′ to 5′ to intercept the defective zones at different depths. The shafts and the trench in the crushed zone in block 54 mentioned above were given special grouting treatment as under : Since the rock was very much crushed it could not take high pressures. So two stage drilling and grouting was adopted. First upper portions of the rock were consolidated at low pressure and then the lower ones at high pressure. The holes were first drilled to 12′ depth and grouted at 30 P.S.I. After 24 hours, the holes were redrilled to full depth of 30′ and grouted at 75 P.S.I. During grouting operations, pressure was controlled to see that there was no uplift pressure. The holes in the shaft and the trench were drilled radially at close intervals. While concreting the shaft and the trench, grout condulets were embedded at 10′ and 5′ intervals at the contact planes of vertical or inclined rock faces to grout later the opening at the junction of rock and concrete after shrinkage. From these, pipes were taken up to the foundation gallery. In this block with low level of foundation and fault zones, there is a special foundation gallery 27′ below the main foundation gallery with transvers gallery running along

Air water jetting of foundation before laying concrete.



Diamond drilling with wagon drill for consolidation grouting.
Right:
Diamond drilling the gallery for curtain grouting.

the fault zone. Curtain grout in this block is done from the lower foundation gallery. The lower foundation gallery is connected with the upper foundation gallery by 3′ diameter vertical shaft.

3" diameter pipes also were embedded in concrete in the shaft as well as in the transverse trench and extended upto elevation 515, the river bed level there, and deep holes were drilled through these and grouted at pressure of 100 P.S.I.

In this portion and in the blocks in the hill slope 30′ deep holes were drilled into the upstream face of excavation at intervals of 10′ after every 5′ lift of masonry and grouted to stop leakage of water. On all the sloping or vertical faces of rock against which the concrete contacted, condulet pipes were left and grouted later after shrinkage.

Number of observation holes 30′ deep were drilled in the foundation grouted area and 1″ pipes were extended therefrom to the foundation gallery for observation of percolation and measurement of uplift pressure.

In blocks 38 and 39, in major portion, the foundation rock was highly crushed, fractured and full of springs. In addition to other foundation treatment, secondary grout along the axis holes 60′ deep at 10′ centres were put in. In case of weak zones, pipes were projected and subsequently grouted under pressure after sufficient depth of concrete was placed to stand the pressure.

Power House Foundations

In Units 1 and 2 there were numerous springs, hence the foundation rock was grouted intensively in the whole area at close intervals with 20′ deep holes and all the springs and seepage were stopped.

Cleaning and Preparation of Foundations

With the nature of the rock described above, cleaning and preparation of foundation to receive concrete was a colosaal job, very tedious and slow. All the weathered loose portions were removed with chisel and hammers. Brown or yellow crust on hard rock surface was removed by sand blasting, Jack Hammering and strong air water jetting. All the joints and crevices, pot holes were cleared of dust and debris and whole surface cleaned with wire brushes and air water jets before receiving concrete.

Curtain Grouting

To cut off leakage and seepage through the foundation of the Dam, curtain grouting is done. High pressure cut off curtain grouting has been done through out the concrete and masonry Dam from the floor of the foundation gallery except in Left Spillway, where there is no foundation gallery, but a three ft. Header where grouting was done from the sill of the sluices. This was started after the Dam was built to a height of about 100 ft. from the foundations.

4″ dia. pipes were placed in the floor of the foundation gallery or sills of the sluices to avoid cutting of reinforcement rods during the course of drilling. Holes for grouting were drilled through these pipes. In the case of Left Spillway overflow portion, three holes were drilled in each sluice—one in the centre and one on either side near the piers. The central hole was drilled vertical and the two side holes were drilled at 12° to the vertical towards the pier. In case of found-

Another view of air water jetting of foundation before laying concrete.

ICI

We are proud to have contributed to India's progress by supplying the Commercial Explosives required during the construction of the Hirakud Dam.

IMPERIAL CHEMICAL INDUSTRIES (INDIA) PRIVATE LIMITED
Calcutta Bombay Madras New Delhi

ICG 637

BROS. LTD. Holman
CAMBORNE . ENGLAND

Portable, Stationary Air Compressors, Rockdrills and ancillary equipment including Tungsten-Carbide tipped "Holsteels", Pneumatic Tools of all types for metal working.

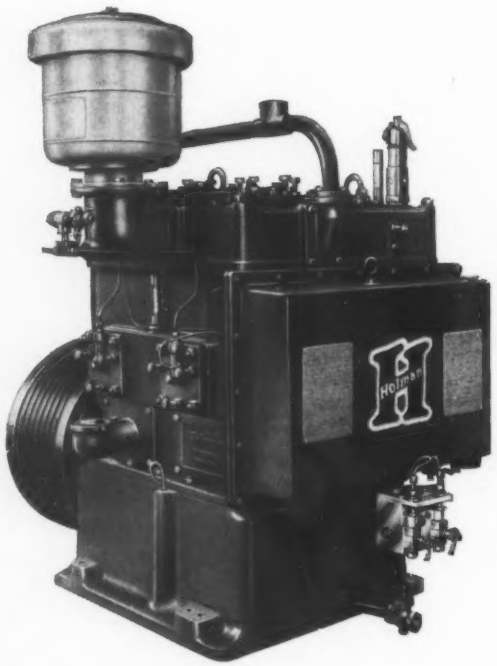
Sole Agents: BIRD & CO. (PRIVATE) LTD., Calcutta, New Delhi & Kanpur.

Sub-agents: KILLICK NIXON & CO. (PRIVATE) LTD., Bombay.

BEST & CO. (PRIVATE) LTD., Madras

ASSOCIATED ELECTRICAL INDUSTRIES (INDIA) PRIVATE LTD., Nagpur.

"HOLMAN" AT HIRAKUD:



"Holman" equipment supplied to the Hirakud Project includes Rockdrills and ancillary equipment, Portable Air Compressors and a battery of six Type "TM60S" Stationary Air Compressors as illustrated in this advertisement. This battery of compressors was installed in 1951 and since then has been supplying compressed air for quarrying operations. Each compressor is electrically driven and delivers 535 cubic feet of free air per minute at 100 lb. per sq. in.

HOLMAN—THE FIRST NAME FOR LASTING SERVICE.

ation gallery, holes were drilled 20 ft. apart and at 12° to the vertical towards the axis. The depth of the holes was 60 ft. below bed rock.

For grouting, split spacing method was adopted. First, the holes were drilled and grouted at 40 ft. apart and then the intermediate holes were drilled and grouted. In this manner, the grouting was completed with such spacing as was warranted by the results of grouting to obtain a continuous grout curtain. In the lowest gallery at E.L. 470, the grout zone in blocks 53 and 54, the spacing of holes was as close as 2½ ft.

Pressure used for curtain grouting ranged from 200 lbs. per square inch to 150 lbs. per square inch. The pressure was localised by packers in the holes. Grouting was done in three stages and pressures applied were as under :

First Stage : Packer fixed 30′ below foundation rock level. Pressure applied, 200 P.S.I.

Second Stage : Packer fixed 5′ below foundation rock. Pressure applied, 150 P.S.I.

Third Stage : Packer fixed at one ft. below concrete surface. Pressure applied, 40 P.S.I.

Foundation Drainage

In spite of low pressure foundation grouting and curtain grout, even if there is seepage or leakage through foundations to cause uplift pressure, it is released by foundation drain holes. The drainage holes in Right Spillway, Power Dam and Left Spillway non-over flow portion are drilled from the floor of the foundation gallery through 3½″ pipes placed in the floor at 20′ and 50′ deep. In case of the Left Spillway, the holes were drilled from the Cill of the sluices through 3 ft. dia header. The holes remained open upto the header and the drain pipes above the header were capped. Thus the drainage was collected in the drainage header running horizontally below the Cill of the sluices in the sluice portion of the Left Spillway. The drainage holes were drilled after the grouting was completed.

Internal Drainage System

If there is seepage through the concrete or masonry from the face of the Dam, it is collected through internal drainage holes which discharge into the drains in the galleries.

The internal drainage is provided by 8″ drain formed vertical holes discharging into the foundation gallery or into the operation gallery. In case of masonry, the drain holes are formed with porous concrete blocks (5½ parts of aggregate to one of cement and no sand). At all the contraction joints, formed vertical drain holes are located 7′ downstream of the axis, while those between the contraction joints in the case of Power Dam and transitions are spaced 10′ centres, located at 12′ from the axis and those in the Spillway at 30′ centres and 12′ from the axis.

Equipment used for Drilling and Grouting

Wagon drills 'Ingersol Rand' consisting of X-71 WD Drifter on FM-2 mounting.	..	6 Nos.
'Thor' consisting of model 105 Thor Drifter with BW 1 mounting.	..	2 Nos.
Diamond Drill E.S. Longyear.	..	3 Nos.
Sprague and Henword.	..	2 Nos.
Ingersoll Rand Calyx.	..	1 No.
Craelious (Seveuska)	..	5 Nos.
C.P.T. Model 55 A pneumatic	..	4 Nos.

Gtout Pumps

Gardner Denver double acting reciprocating with 4″ suction and 2″ delivery driven by Caterpillar diesel engine Model D-34. Diameter of pump piston 4″ and stroke 6″	8 Nos.
'English' Monalith with Lester engine (used for short time).	3 Nos.

Air was taken from Air Station with a battery of compressors.

The grouting pump had a mixer of 21 cft. capacity, an agitator of 18 cft. capacity. The mixer and agitator were manufactured in the project workshop and was operated by manual labour.

The following figures will show the magnitude of drilling and grouting done in the Dam.

Low Pressure Grouting

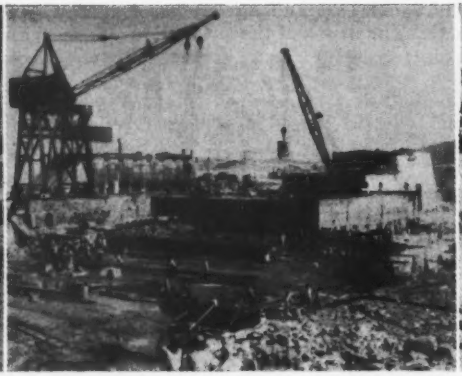
	Total footage drilled. Wagon Diamond Total.		Total footage grouted.	Total no. of bags consumed:	Average per linear ft.
(i) Left spillway.	13562′0″	330′0″	13892′	5936	0.43
(ii) Right spillway.	22375′0″	1614′0″	23989′	3618	0.15
(iii) Power dam and power House.	33521′0″	1105′0″	34626′	7034	0.25
High Pressure Grouting					
(i) Left spillway.		7720′	7720	3842	0.50
(ii) Right spillway & Power dam		10283	9980	2909	0.30
Cut off grouting (in Earth Dam Portions)					
(i) Left Earth dam	4358	2100	6458	17378	2.80
(ii) Right Earth dam.	6480	864	7344	6715	0.91
(iii) Left dyke gap 1 & 2	2571	120	2711	1529	0.59

Concreting

Aggregates

The coarse aggregate used was of crushed granite rock, river shingle or a mixture of both. Good hard granite rubble was brought in B.G. wagons from quarry at a distance of 5 miles from the left side and 10 miles from the right side. There was a crushing plant on each side of the Dam, consisting of wagon tippler, apron feeder, Greundular jaw crusher 42″×24″, P-20 Gyratory crusher, apron feeders under reserve stock pile, one P/37 and two 8½ secondary Gyratory crushers with necessary screens and conveyors. As each crushing plant could not give the required quantity of aggregate, three individual crushers with screening and grading arrangement were also worked at the quarry. River shingle screened to separate and required grades was used as much as available within reasonable distance. On the left side, three grades were used 3″+1½,1½″+¾″, and ¾+$^{3}/_{16}$″ On the right side cabbles —6″+3″ were also used in

Concreting foundations during 1951-52. Individual mixers were placed at each block and concrete was being carried by tip wagons travelling on temporary trolley track within the foundation pit.



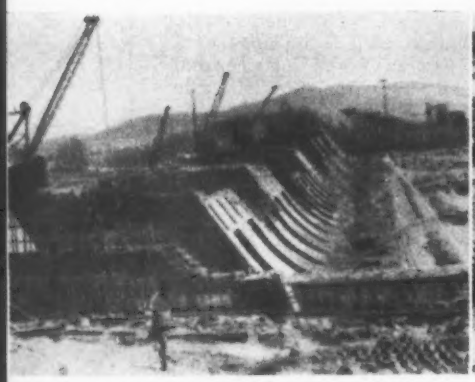
Concreting with cranes 1951-52. Only two cranes —one Clyde and one Lorain were used. Concrete used to be supplied from the locally made batching plant.

Vibrating the concrete with a two-man vibrator.

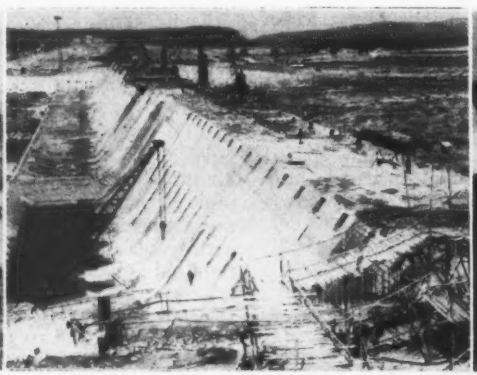
Back-filling the seams. This work was done with utmost care under strict supervision.

Concreting in the bucket portion. Concreting was done by manual labour and finishing with floats. The finishing was being done by expert masons under constant supervision. Curving was being done with wet sand bags for three weeks.

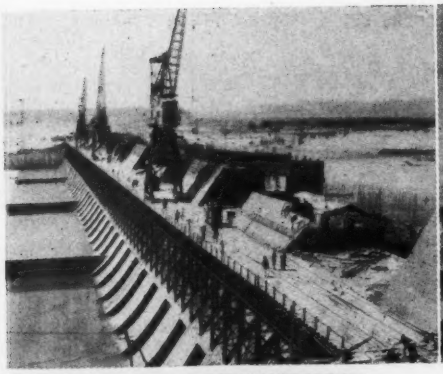
Concreting in 1953-54 season with 4 cranes on the upstream side of the Left Side Dam. The Dam was raised to E.L 560.0 completing all the 40 sluices during this season.

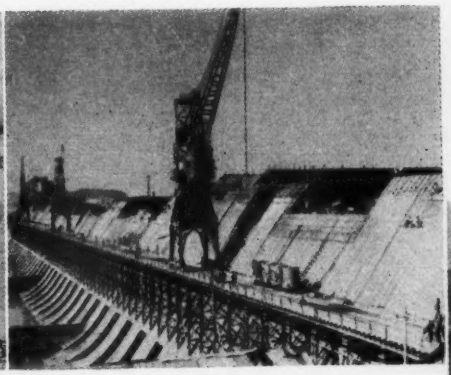


View of Left Spillway when the season's programme was completed on half the Dam. All the four cranes are working in the other half. The Block outs left for the erection of the Trestle Bridge to carry the cranes may be seen.



Left Spillway after the season's programme. The cranes and the river bed as was being done every year. During the season 53-54, both the Blaw-Knox and the locally comprised batching plant were being used and about 28 lakhs of concreting was done.

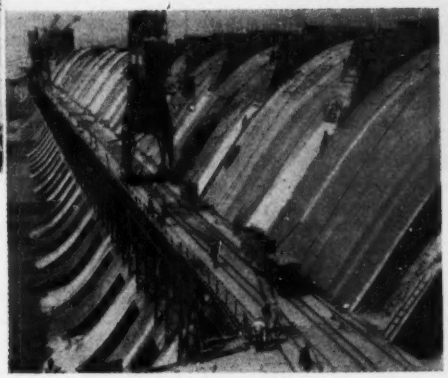


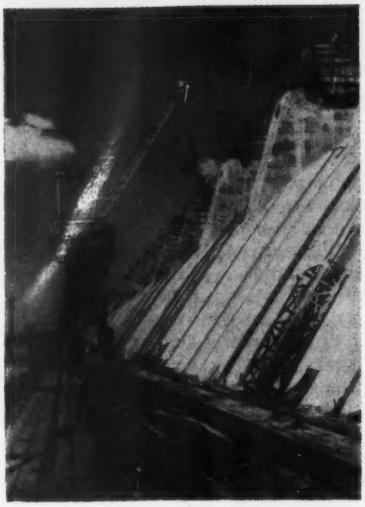


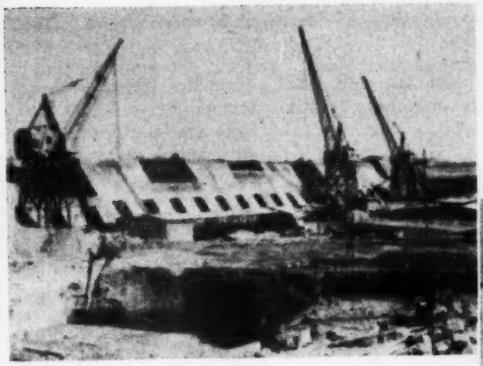
Extreme Left: **The trestle bridge on the rear slope of the Left spillway**

Left: **The Crest taking shape in the Left spillway.**

Bottom: **Left Spillway with crests completed.**

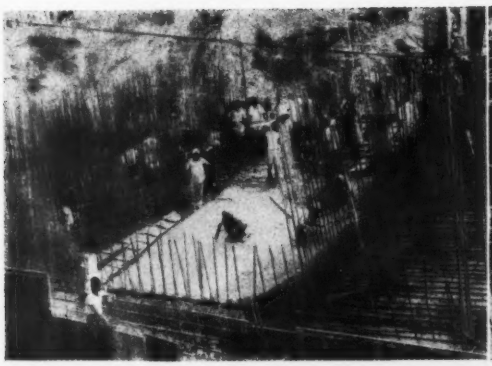


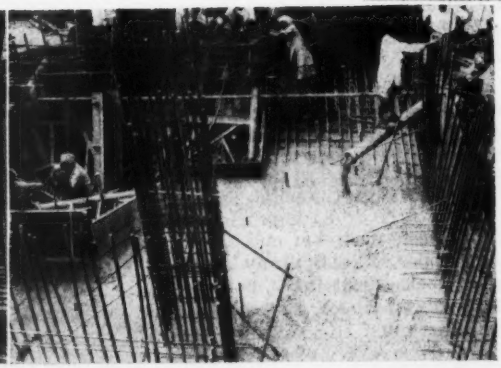




Left: **Concreting in piers.**

Top: **The 120-feet boom washing crane in operation on Right spillway.**





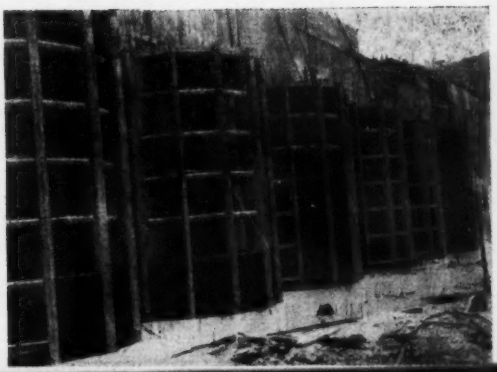
Top: **Concreting of piers Right spillway**

Extrem: Left: **Finishing the floor of the Draft Table.**

Left: **Concreting with concrete pump.**

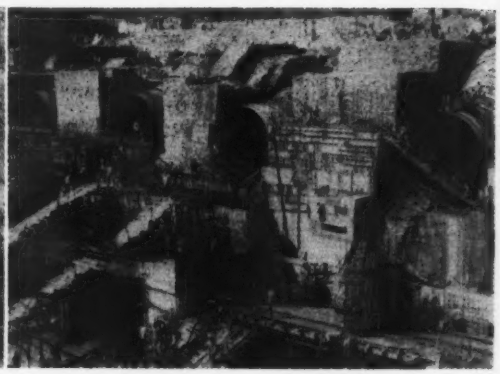
Right : **A view of Power House during construction.**

Extreme Right: **Trash rack structure.**



Masonry work in the Transitions. A forest of ballies forming the scaffolding ladder for a height of eighty feet. Stone and mortar for masonry were carried up by mannual labour.

Masonry work in Power Dam portion.



Concreting in Power House and masonry in Power Dam. Blockouts were left for the penstocks. After erection of the liners, concreting around them was done with the Concrete Pump.

mass concrete in some portions. On the left side cables could not be used as the batching plant consisted of one cu. yd. mixers.

Sand

Clean river sand of approved quality was available in river bed within three miles distance and was used.

Cement

Cement was obtained from Rajgangpur factory in bags, 70 miles from the Dam site. The factory had no arrangement for supply of loose cement and therefore supplied in bags.

Composition

Tests and analysis of the aggregates were made in the Research Laboratory and mix was designed to secure the required workability, density, impermeability, strength and practical economy. Such tests and analysis were made at frequent intervals during the progress of the work and mix adjusted if it warranted any change. Air entraining agent was used to reduce water cement ratio and get better workability. Slump tests and samples for determining compressive strength were taken frequently in every shift.

Strengths

Mix for mass concrete in Spillway Dam, foundations of Power Dam and Transitions except 5 ft. outer portions and in Spillway bucket except top three ft., Power House sub structure, was designed for 2000 lbs. minimum.

In the outer 5 ft. of crest, upstream and downstream faces of Spillway, upper 3 ft. of Spillway bucket all R.C.C. in sluices, penstocks, draft tubes, galleries, piers, superstructure of Power House, the mix was designed for 3,000 lbs. minimum.

Mixing

Two batching plants were erected, one on either side. On the left was Blawknox, consisting of 8 one cubic yard mixers and on the right was the Winget, consisting of 4 three cyd. mixers. Before Blawknox batching plant was received, an improvised batching plant consisting of 12 half cyd. Ransom mixers electrically driven was rigged up on the left side. It was partly worked by power and partly by manual labour. All disposal mixers and materials were used. The mixers were arranged in two rows opposite each other, discharging into wet hoppers over the trench, which discharged into buckets on trollys driven by loco on N.G. track. One set of bins made of pontoon plates was erected on either side which were fed by dumpers and trucks on a ramp. At the bottom of each bin, gate hopper with weighing scale was fixed, which discharged into the tip wagons, driven by manual labour which fed the mixers. This plant worked afterwards too in addition to the Blawknox plant. When the concreting on left side was finished, it was moved to upstream of Power Dam for concreting around penstocks, gate slots, galleries and trash racks and top cap. This rigged up batching plant gave good service and very little to go wrong with it in comparison with the other plant.

Conveyance of Concrete

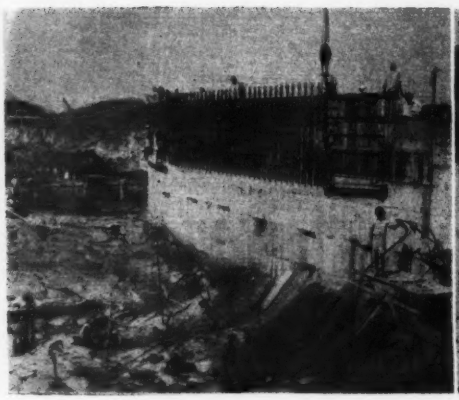
Mixed concrete was conveyed, (*i*) in 2 cyd. and 3 cyd. buckets on trollys, driven by 30 H.P. locos on N.G. line, (*ii*) in tip wagons driven by 30 H.P. locos, (*iii*) Mac dumpers with carriage capacity of 18 tons and dumped directly into position, (*iv*) Belt conveyor. Concrete was conveyed in buckets which discharged into the hopper feeding the conveyor. The latter discharged the concrete into position wherever required. The buckets for concreting and the conveyors were manufactured in our own workshop.

Placing

This had to be arranged according to the cranes available. We were restricted to the cranes with 75′ and 60′ boom, which were received from the disposals. The two new Washington cranes with 125′booms were received only in 1954-55. On the left side, Clyde cranes with 75′ boom and Stothert and Pitt cranes with 60 ft. boom were used. On the right side, Clyde cranes with 75′ boom, steam derrics with 110 ft. boom and Washington cranes with 125′ boom were used.

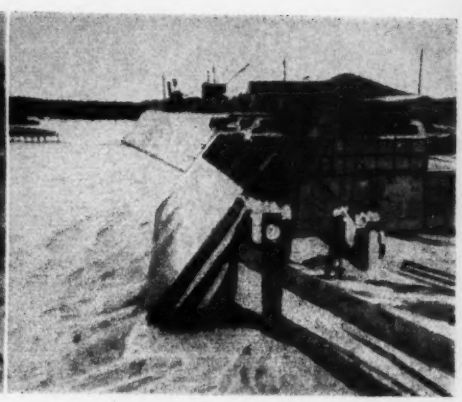
On the left side, structure was raised to E.L. 557 i.e., 47 ft. above Cill level by four cranes working on the upstream side. Concreting in bucket was done by Loraine crane and by manual labour. Trolley track was laid on ground or bed of the river on suitable formation.

For concreting above E.L. 557 upto top of piers (E.L. 634), staging for cranes was constructed on the downstream slope of the Dam and placing of concrete



Erection of shuttering for contraction joints. 2 1/2 ft. square plates with stiffener angles adopted.

Another view of the shuttering under erection.



Shuttering for contraction joints.

was done by three Stothert and Pitt cranes. Trolley track was laid on a ramp from the batching plant to the staging with a maximum grade of 1 in 30 and over the staging at E.L. 557. Concreting for bridge decking and parapets was done with portable mixers placed on the top of the Dam and by manual labour.

On the Right Spillway, concreting upto E.L. 560, i.e., upto 50′ above Cill level, was done by Clyde cranes and steam derricks, placed upstream and downstream. Above elevation 560, it was done by two Washington cranes with 125′ boom placed on earthen formations at E.L. 518 at the downstream of the Dam over the bucket. Concreting of bridge decking, parapets and road was done with portable mixers and manual labour as stated for the Left Spillway. Concrete for penstocks and galleries in Power Dam was done with Clyde crane and that in Power House was done with concrete pump, right upto its roof where there was no reinforcement, 15% plums were added to concrete discharged by the pump.

Stone Masonry

All the transitions, non-over-flow blocks and Power Dam are constructed in masonry. Foundation concrete was laid for about 5 ft. depth over the rock foundation base. Over that was taken the masonry. On the faces, hammer dressed stone masonry in 12 inch regular courses was done and in hearting random rubble masonry was done. Cement mortar used was 1 : 3 in faces upto 5′ and 1 : 4 in hearting. All the materials were carried by manual labour on scaffolding staircases made of ballies, ducklies, bolts and necessary iron hooks and wire ropes for fastening. In case of Power Dam at higher elevations, mortar was lifted by Clyde crane. Rubble was quarried by pneumatic drilling and hand drilling and blasted with gelegnite. Carriage was done by trucks. Mortar was mixed in half cu.yd. and one cyd. mixers. In case of concrete, one has to depend entirely on machinery. If one link goes out of order, the whole production suffers. In case of masonry, mixers is the only machinery to be taken care of. The rest is all manual labour. Hence it is least troublesome and progress is assured. It is also cheaper than concrete by about 50% per unit.

In the filling between Power Dam and Power House, German masonry was also useed. Dry rubble was laid about 2 ft. thick with voids left. Pump concrete was pumped into the rubble and two-new-men C.P.T. pneumatic vibrators worked through the voids to inject concrete through and fill up the joints.

Air Supply.

Air was taken from central station fixed at various sites at a pressure of 100 lbs. per sq. inch. There was one station with 6 Holman compressors of 500 C.F.M. capacity each electric driven coupled in two batteries (three in each) at the quarry for rubble for aggregate. Second station was in the Left Spillway with 10 Broomwade compressors of 250 C.F.M. capacity each in two batteries (5 compressors in each) for excavation, air water jetting, sand blasting, cleaning, vibrating concrete, drilling and grouting etc. The third station was on the Right Spillway with 6 C.P.T. compressors of capacity 315 C.F.M. each for excavation, air water jetting, sand blasting, cleaning, concreting, drilling and grouting etc. A fourth station was on the Power Dam with 4 C.P.T. compressors of 315 C.F.M. capacity each. Fifth was on the Power House with 4 CPT compressors of 315 C.F.M. capacity each.

Stray portable compressors were used for additional jobs and at various scattered quarries for rubble for masonry, rip-rap and pitching.

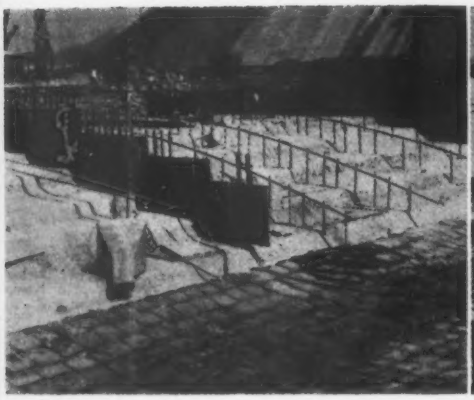
Vibrators.

For consolidation of concrete, two-men CPT vibrators were used. For consolidation in reainforced and difficult zones thinner C.P.T. dwarf vibrators 3″ dia. and Ingersoll Rand 1V & 2V were used.

Form Work.

All forms were made of steel and were made of light panel steel plates for longer life, convenience of handling and smooth surface and ultimately were economical than wooden shuttering. The forms with which we completed our Dam are now being sold to other projects for further use and they get ready made forms which have proved efficient and useful.

Forms for vertical and sloping faces and contraction joints are made of $2\frac{1}{2}' \times 2\frac{1}{2}' \times \frac{1}{8}''$ M.S. plates with $1\frac{1}{2}'' \times 1\frac{1}{2}''$ angles on all sides and ribbed in one direction in the centre. The angles have slots to take cotters. After fixing the plates, horizontal and vertical bracings of angles are used. The horizontal bracing is fixed to the plate with a lock plate and vertical bracing with 5″ bolts. Ties and struts are also used. Ties



Templates for the Sill of Sluices in position.

Bucket shuttering ready to receive concrete.

Bucket shuttering after concreting has been completed.

consisted of 6 strands of 15 gauge G.I. wire. twisted round. The struts were made of G. I. pipes. A sharpened iron rod was welded at bottom and a nut at top. A fully threaded holt with forked head was placed in between the form and the strut for adjustments. Tie loops were made of 1/8″ iron rod loop welded to a nut.

In case of downstream curved portion at the rear of the Dam upto the sluice level curved portion on the crest and bucket, profiles to the required shape made of channels and fixed by angles as vertically fitted with nuts and bolts on the top for adjustments, were used. Open screeding was done while concreting.

Sluice Shuttering

Special steel shuttering was made for sluice. 6′×4′ plates were used for the roof. For ball mouth and the doustream sides, plates were made to the required shape and curvature. For straight sides usual 2′×2′ plates were used.

3′ *Header in left Spillway*

Collapsible shutters in 5′ lengths were made for this. Frame was made of angles in 3 pieces, coursed with planks and G. I. sheets.

5′×7′ *Gallery.*

For sides 2½′×2½′ steel plate suttering was used as stated for vertical and sloping sides of Dam and contraction joints. For semi-circular roof, steel shutters manufactured in 3 segments were used.

Operation gallery.

2½′×2½′ steel plate shuttering was used as for vertical sides of the Dam. For haunches 2½′×2½′ plates with wooden plank for 3″ gap fitted with special frame were used.

Sump wells and staircase walls

This was made of curved steel plates on angle frame in 3 pieces.

Formed Drainage Holes in the Body of the Dam

The form work for these was only a 8″ dia. steel pipe which was kept moved by rotating after the concrete had partially set and taken out 8 hours after concreting. In case of masonry, the holes were made with steining of porous concrete blocks.

Transition for Penstocks.

Separate shuttering for English and German units were made. They were made of steel frame work. The top was covered with planking carved to required shape and then covered with G.I. sheets. Wood covering was used because of special carving which could be taken by wood only.

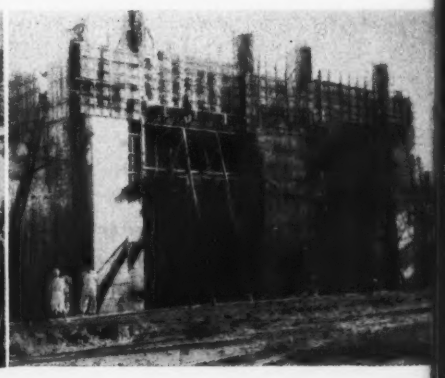
Draft Tubes.

Shuttering for these was made entirely of steel plates, for English and German units separately.

First lift of sluice shuttering under erection. This was an intricate work requiring perfect alignment and accurate adjustment.

Sluice shuttering at various lifts.

Shuttering for the roof of sluices in positio



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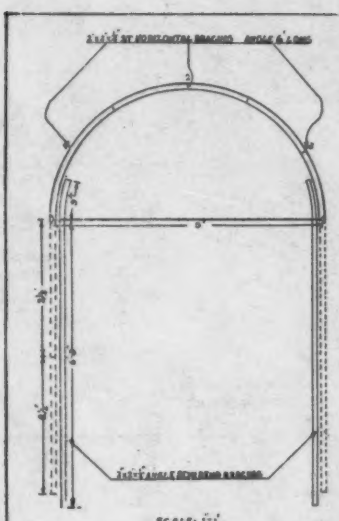
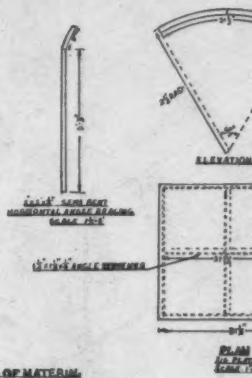
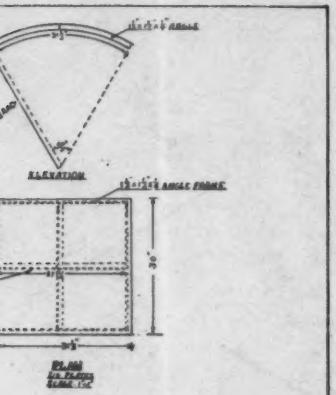




BILL OF MATERIAL.

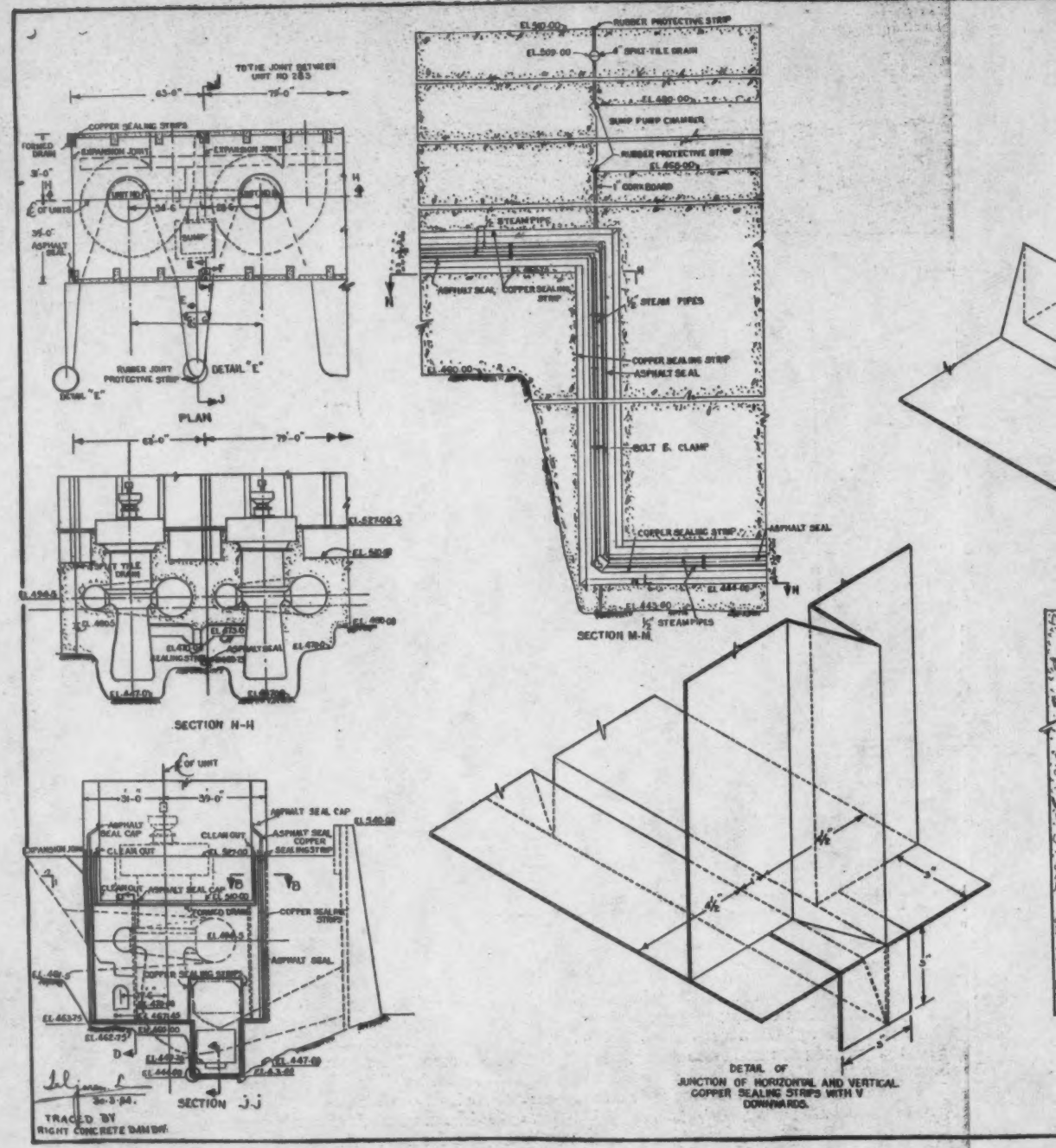
1. LOCK PLATES 240 MM. FROM ½" PLAT
2. [illegible] COVERS FROM ½" PLAT
3. 40 MM BEAMS 3"x3"x½" ANGLE STRAIGHT HORIZONTAL BRACINGS.
4. BOOMS & EACH SEMI RECT HORIZONTAL BRACING 3"x3"x½" ANGLE.
5. 2 MM CURVED PLATES.

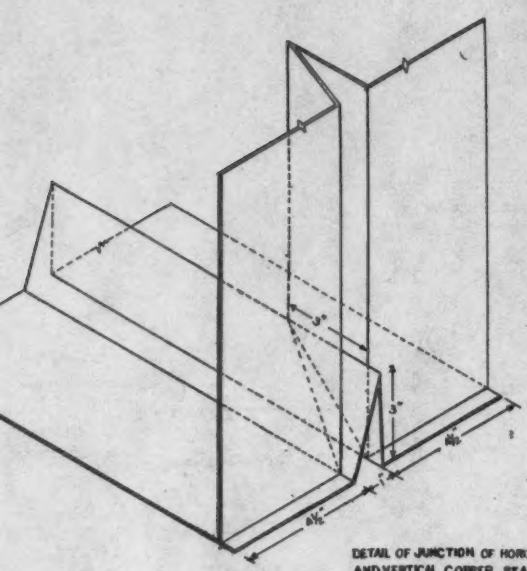


HIRAKUD DAM PROJECT
MECHANICAL DIVISION

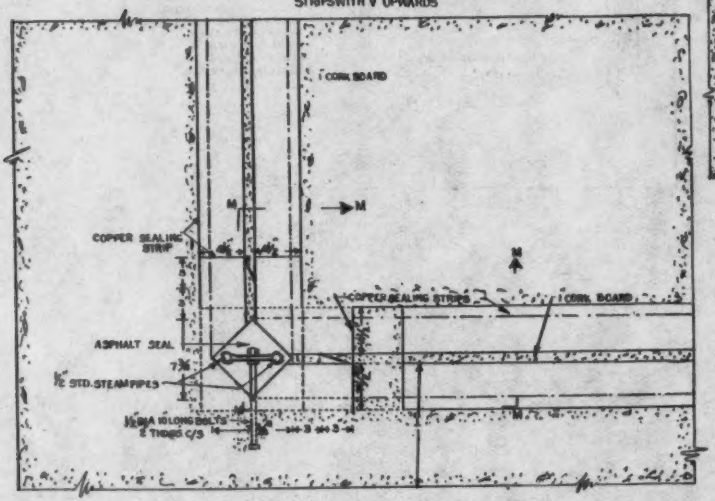
SEMI-CIRCULAR GALLARY
SHUTTERING

DESIGNED BY	
TRACED BY	
COMPARED BY	EXECUTIVE ENGINEER
	DRG. No 156


TO THE JOINT BETWEEN UNIT NO 283
63'-0"
75'-0"
COPPER SEALING STRIPS
EXPANSION JOINT
EXPANSION JOINT
FORMED DRAIN
3'-0"
℄ OF UNITS
35'-0"
ASPHALT SEAL
UNIT NO 284
UNIT NO 285
54'-6"
58'-6"
SUMP
RUBBER JOINT PROTECTIVE STRIP
DETAIL "E"
DETAIL "E"
PLAN
63'-0"
75'-0"
EL 527.00
EL 510.0
EL 494.5
EL 460.0
EL 473.0
EL 480.00
EL 470.0
ASPHALT SEAL
EL 470.0
EL 447.01
SECTION H-H
EL 560.00
RUBBER PROTECTIVE STRIP
EL 509.00
6" SPLIT-TILE DRAIN
EL 480.00
SUMP PUMP CHAMBER
RUBBER PROTECTIVE STRIP
EL 466.00
1" CORK BOARD
½" STEAM PIPE
ASPHALT SEAL
COPPER SEALING STRIP
½" STEAM PIPES
COPPER SEALING STRIP
ASPHALT SEAL
EL 460.00
BOLT & CLAMP
COPPER SEALING STRIP
ASPHALT SEAL
EL 443.60
EL 444.60
½" STEAMPIPES
SECTION M-M
℄ OF UNIT
31'-0"
39'-0"
ASPHALT SEAL CAP
EL 560.00
ASPHALT SEAL CAP
CLEAN OUT
CLEAN OUT
ASPHALT SEAL COPPER SEALING STRIP
EXPANSION JOINT
CLEAN OUT
EL 527.00
CLEAN OUT
ASPHALT SEAL CAP
EL 510.00
FORMED DRAIN
COPPER SEALING STRIPS
EL 494.5
ASPHALT SEAL
COPPER SEALING STRIPS
EL 460.0
EL 463.75
EL 462.75
EL 467.65
EL 460.00
D
EL 460.00
EL 447.00
EL 444.00
EL 443.60
SECTION J-J
TRACED BY
RIGHT CONCRETE DAM DIV.
½"
3"
½"
3"
3"
DETAIL OF JUNCTION OF HORIZONTAL AND VERTICAL COPPER SEALING STRIPS WITH V DOWNWARDS.

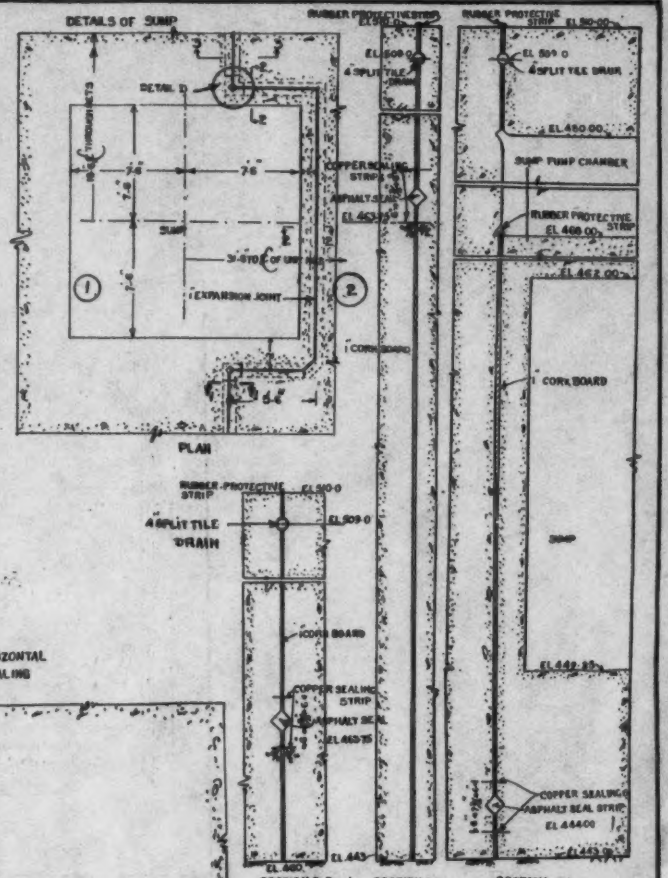


DETAIL OF JUNCTION OF HORIZONTAL AND VERTICAL COPPER SEALING STRIPS WITH V UPWARDS



DETAIL AT D
(PLAN ALONG N-N)

NOTE :—
FOR SECTIONS B-B, D-D E-E, F-F AND G-G REFER DRAWING NO. 100-3M-46A.



SCALE — DETAIL D (PLAN ALONG N-N) — 6 3 0 6 INCHES
SCALE — PLAN AND SECTION HH — 25 0 25 FEET
SCALE — SECTION J-J — 20 15 10 5 0 20 FEET
SCALE — DETAILS OF JUNCTION OF HORIZONTAL-VERTICAL COPPER SEALING STRIPS — 2 1 0 3 INCHES
SCALE — SECTION 11, B-B & D-D — 2 1 0 2 FEET
SCALE — DETAILS OF SUMP PLAN — 4 2 0 4 FEET

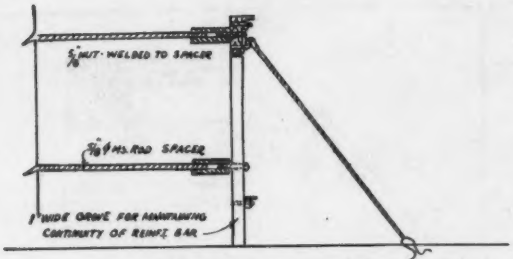
GOVERNMENT OF INDIA
CENTRAL WATER & POWER COMMISSION

HIRAKUD DAM

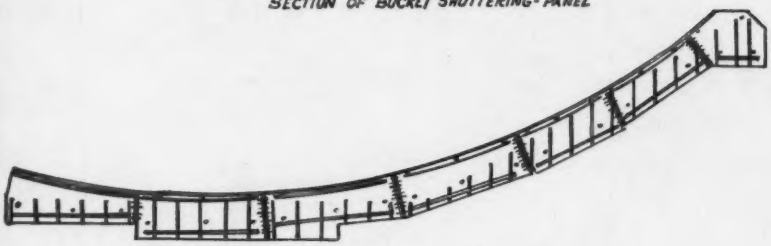
MAIN DAM

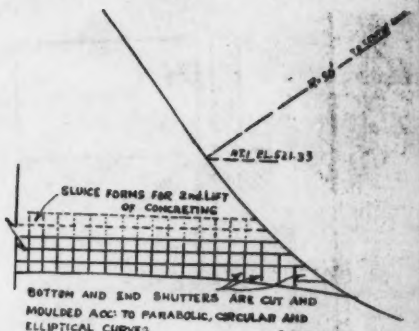
JOINT DETAIL FOR POWER-HOUSE UNITS 1 & 2

DRAWN S.C.	SUBMITTED	T.R.M. MURTHY
TRACED L.L.R. & H.C.R	RECOMMENDED	K. L. RAO.
CHECKED M.V.D.	APPROVED	
	NEW DELHI. JAN. 1954	100-3M-46

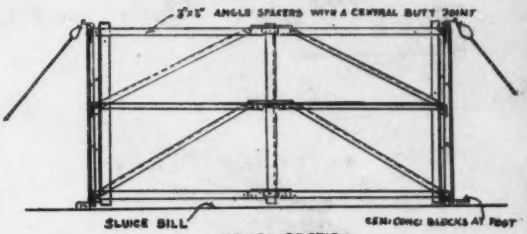


SECTION OF BUCKET SHUTTERING - PANEL



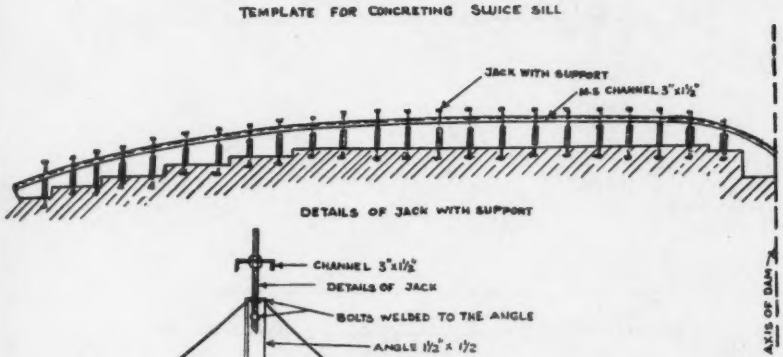

R=50'-0" TANGENT
REF. EL 521.33
SLUICE FORMS FOR 2nd LIFT OF CONCRETING
BOTTOM AND END SHUTTERS ARE CUT AND MOULDED ACC: TO PARABOLIC, CIRCULAR AND ELLIPTICAL CURVES
CONTRACTION JOINT
RADIAL

MAIN DAM SPILLWAY BLOCK

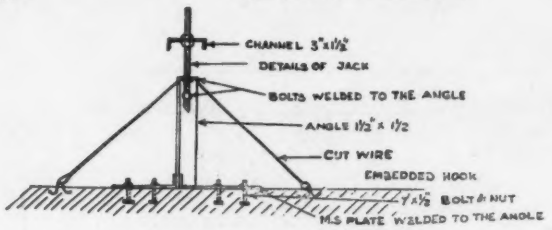


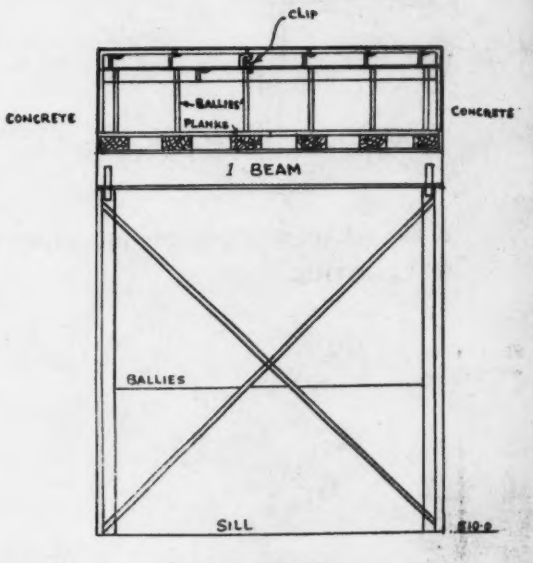
CROSS-SECTION SHOWING ARRANGEMENT OF FORMS FOR SLUICE SIDES

TEMPLATE FOR CONCRETING SLUICE SILL

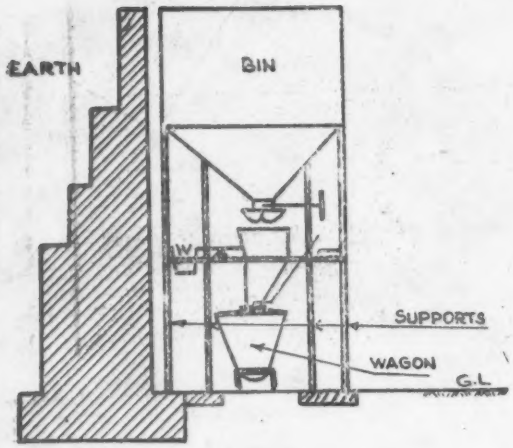


DETAILS OF JACK WITH SUPPORT

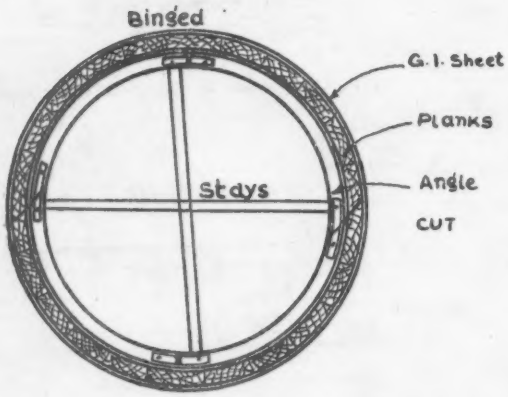


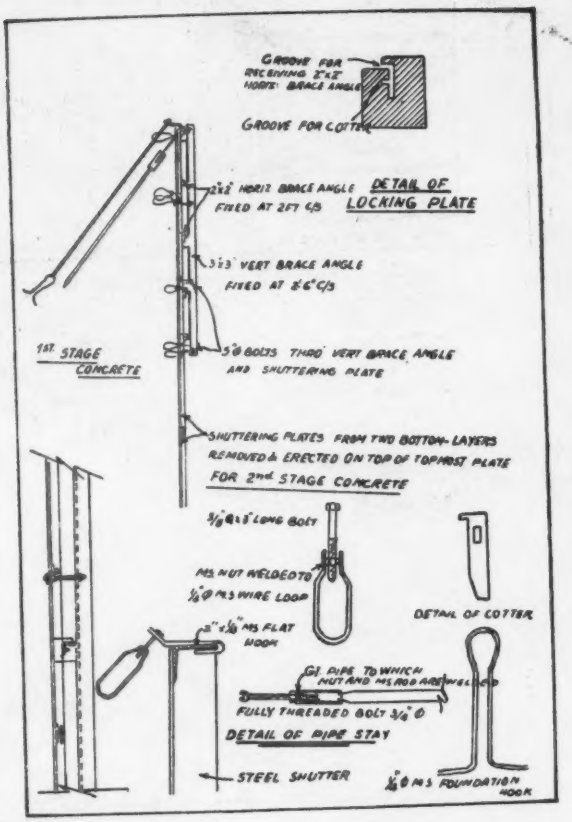


SLUICE ROOF FORMS

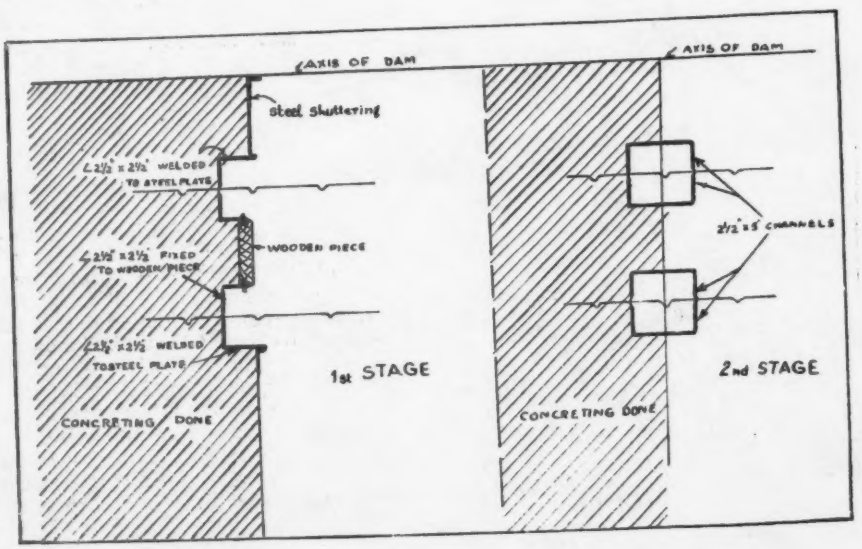


BATCHING PLANT




GROOVE FOR COTTER
2"x2" HORIZ BRACE ANGLE FIXED AT 2FT C/S
DETAIL OF LOCKING PLATE
3"x3" VERT BRACE ANGLE FIXED AT 2'6" C/S
1ST STAGE CONCRETE
5/8" BOLTS THRO' VERT BRACE ANGLE AND SHUTTERING PLATE
SHUTTERING PLATES FROM TWO BOTTOM-LAYERS REMOVED & ERECTED ON TOP OF TOPMOST PLATE FOR 2nd STAGE CONCRETE
5/8"Ø x 8" LONG BOLT
MS NUT WELDED TO 1/4" Ø MS WIRE LOOP
DETAIL OF COTTER
3" x 1/2" MS FLAT HOOK
G.I. PIPE TO WHICH NUT AND MS ROD ARE WELDED
FULLY THREADED BOLT 3/8" Ø
DETAIL OF PIPE STAY
STEEL SHUTTER
1/4" Ø MS FOUNDATION HOOK

3' DIA. HEADER COLLAPSIBLE SHUTTERS IN 5' LENGTHS.



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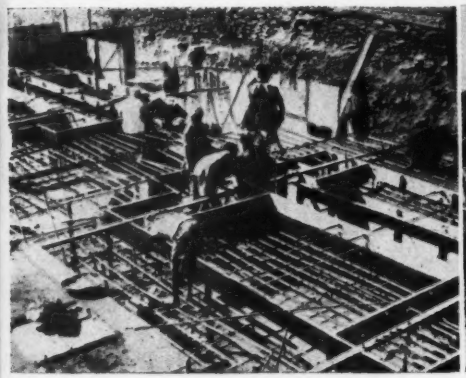
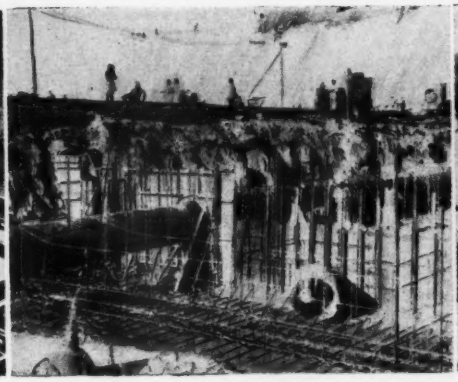
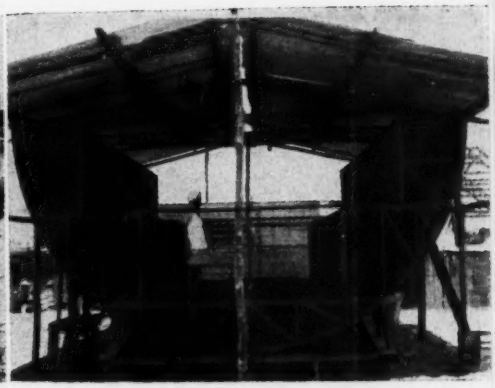


Block out for receiving the embedded parts of the Sluice Gates.



Header shuttering in position



Shuttering for Transition portion of penstocks.

Bridge Decking.

Centring for bridge decking was made for two units of three spans each. Six fabricated steel girders of three spans length were placed and rolled over rollers fixed on piers. After completing three spans, the girders were rolled over another set of three spans. Over the fabricated girders were placed wooden runners with wedges underneath. Over the runners were placed cross battens over which were placed M.S. plates.

Parapets.

Wooden shuttering covered with G. I. sheets was used to keep architectural features.

Scaling of joints: Vertical Faces.

Contraction joints between the vertical faces of two blocks were made watertight with double rows of 16 gauge sealing copper plates. The plates were given three 'V' notches for better bond. Angles were fixed with steel plates for proper shape. Before starting concreting in the adjacent blocks channels were fixed to complete the well. The channels were removed 8 hours after concreting and hot liquid asphalt was poured in the clean well. Similarly copper sealing strip was fixed around the gallery opening at the junction of two blocks.

All contraction, expansion and construction joints are provided with copper sealing strips.

Joints in Power House

Contraction joints have been provided in between the units in the substructure as well as in the superstructure of the Power House from E. L. 447 to E. L. 593.0. These joints have been provided to relieve tensile stresses induced in the structure by shrinkage. Concrete on one side of the joints is cast first and after the form is removed from the joint face one inch thick cork board, coated with asphalt, is put to prevent adhesion of the concrete placed against it.

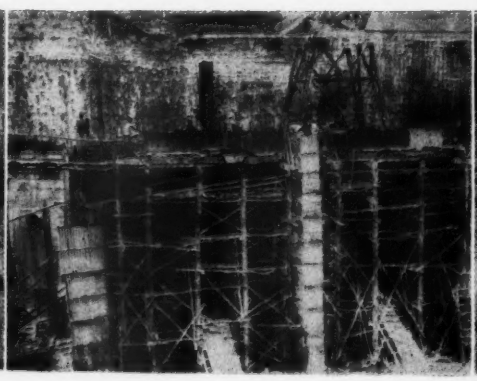
In English units, contraction joints are provided from 3′ above the foundation level whereas in German units 30′ above the foundation level.

Vertical Contraction Joints have been provided in the walls on upstream and downstream sides in the substructure of the Power House and in columns in superstructure of Power House upto E.L. 593. *Horizontal contraction* joints have been provided in turbine floor, generator floor and roof at E.L. 593. These horizontal joints are level and terminate approximately at right angles to the faces of upstream and downstream walls of the Power House.

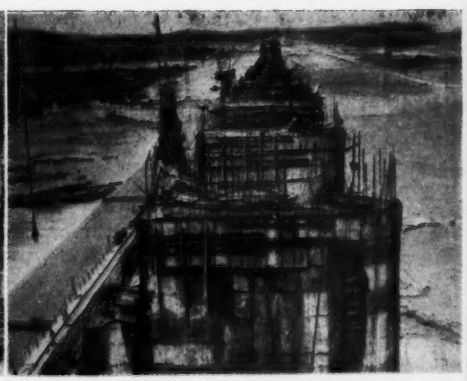
The contraction joints between the units in the superstructure are made continuous through the walls, floors and roof slabs by double R.C.C. columns and doudle floor beams at joints.

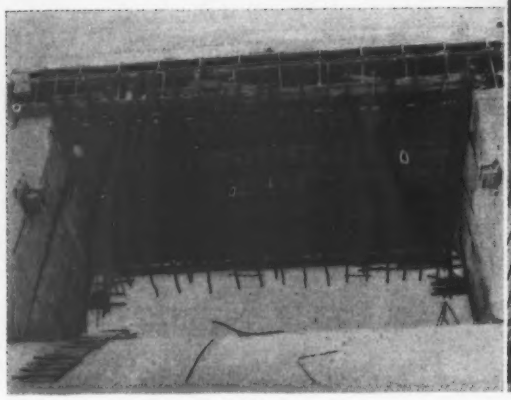
Penstock liners.

Shuttering and staging for the Draft tube roof.



Shuttering for piers.





Centring for a beam of the Spillway Bridge.

First lift of the Form work for piers.

Bottom view of the shuttering for the Spillway Bridge.

Cork board

This is used as joint filler, which is a water proof material. Concrete on one side of the joint is cast first and the form is removed from the joint face. Joint filler, i.e., cork board coated with asphalt is pressed against the surface and then concrete placing is resumed.

These joints have been made further water-tight by use of asphalt seal, copper seals and rubber protective strips. Two copper seals are installed one on each side of a diamond shaped hole which is filled with asphalt. Two steam pipes have been left in diamond shaped hole for re-heating the asphalt. As an additional precaution formed drains have been provided behind rubber water stops.

Cover.

Rubber protective strips have been used to protect the exposed edges of joints and to prevent the ingress of foreign material that might otherwise cause spalling of the concrete edges. These strips improve the architectural beauty also of the structure. Stainless steel straps have also been used, in covering the vertical joints, to hold the rubber protective strips in place.

Galleries.

In the body of the Dam, there are galleries for various purposes :—

(*i*) *Foundation Galleries.* This is meant for drilling and grouting operations, curtain grout and taking drainage water from the drain pipes in the foundation and from formed drain holes in the body of the Dam, and inspection. In the Left Spillway there is 5′×7′ gallery in the Transition portion and 3′ header under the sluices 12′ downstream of the axis. As there was no sufficient headway between the rock foundation and the cill of the sluices, 3′ drainage header was provided, which is connected with 5′×7′ gallery in the Transition portions and there are 4′ diameter manway with adits along the header in block 5, 12 & 19 connecting with sluice at the downstream of the gate for intermediate inspection. In the Right Spillway and Power Dam, there is one continuous gallery 5′×7′ from one end to the oher. In block 53 and 54, where the foundation has gone very much deeper as mentioned in the excavation, lower foundation gallery was provided in addition at 27′ below the upper foundation gallery. This lower gallery has got cross gallery also which runs over the crushed zone. In Power House 5′×7′ gallery runs at elevation 470 with adits for inspection of draft tubes and for dewatering.

Operation Gallery.

In both the Spillways, there is operation gallery 11′×20′ (the biggest in Asia) at elevation 557 for operation of the sluice gates. In the Power Dam, in continuation of this operation gallery runs a 5′×7′ gallery at the same floor level. There is upper gallery in Power Dam at elevation 628 with hoist chambers for operation of penstock gates.

Stair Wells.

There is stair well 6-1/2′ in diameter at the left end of the Left Spillway (block 1 of the left flank wall) with R.C.C. spiral staircase connecting the foundation gallery with operation gallery. 6 ft. dia. stair well in block 1A of left flank wall from foundation level to the top of the Dam, connected at the bottom and top with 10″ dia. plumb hole shaft.

Stair Case.

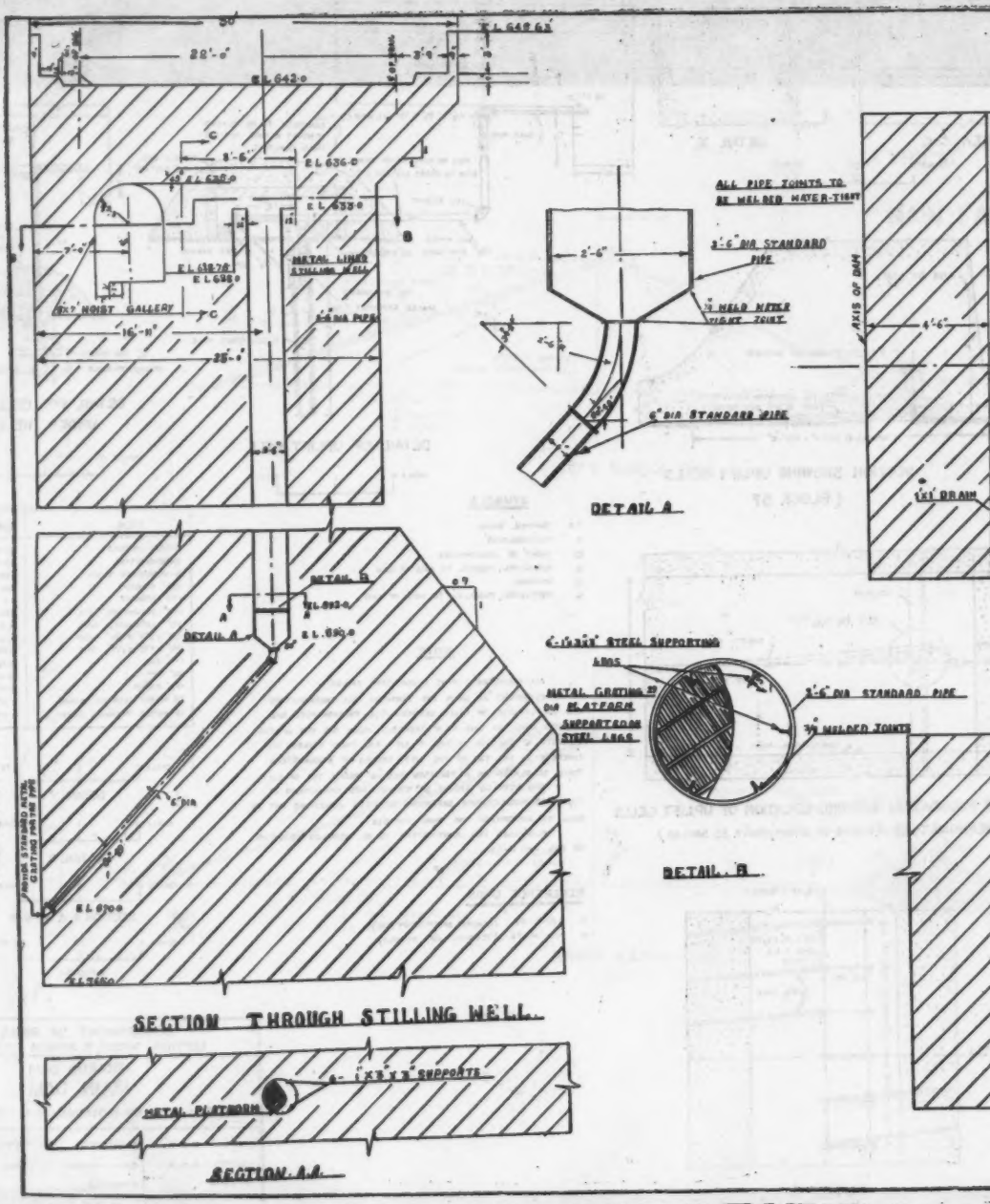
There is stair case 3-1/2′ wide in block 25 of Left Spillway and block 30, and 57 of Right Spillway connecting the foundation gallery and the operation gallery.

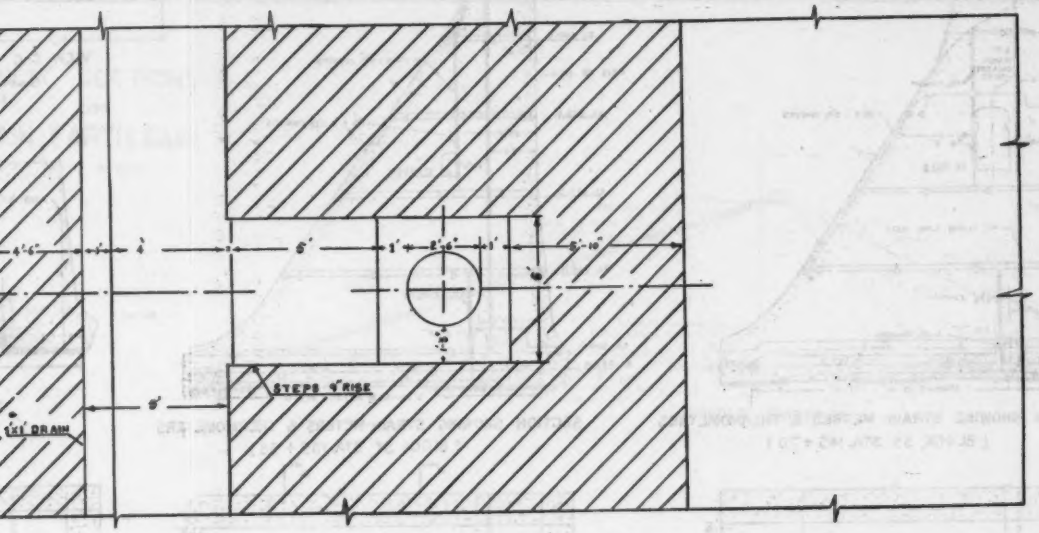
Pump Chamber and Sump Well.

To pump out water from the foundation gallery of the Dam, there is a 6′ dia. sump well in the left flank wall block 1 and block 23 of the Left Spillway; block 32 and 47 of the Right Spillway and in block 53 of Power Dam at E.L. 470 to E. L. 497. In the Power House too, there are sump wells, one between units 1 and 2, and the other in unit 3 and the third in unit 4, provided with pumps to pump out water from sumps in the foundations.

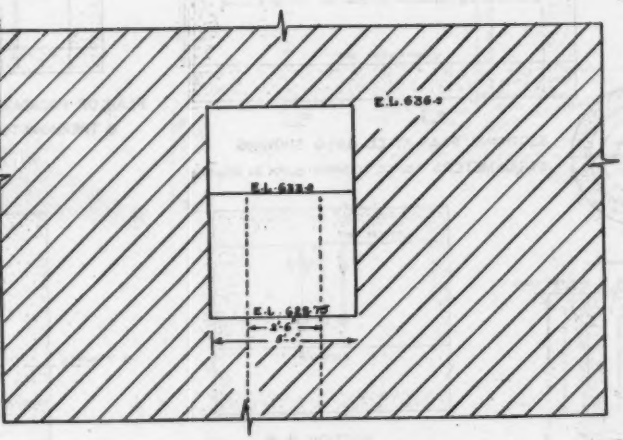
Gates.

All the sluices, crest bays, penstock and draft tube

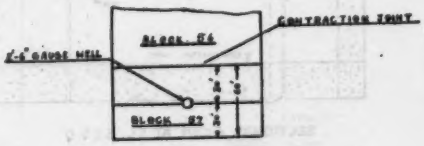

28'-0"
EL 642·0
EL 636·0
EL 632·0
EL 618·78
EL 698·0
METAL LINER
STILLING WELL
GATE HOIST GALLERY
16'-11"
25'-0"
2'-6" DIA PIPE
ALL PIPE JOINTS TO BE WELDED WATER-TIGHT
2'-6" DIA STANDARD PIPE
½" WELD METER TIGHT JOINT
6" DIA STANDARD PIPE
AXIS OF DAM
4'-6"
1½" DRAIN
DETAIL A
DETAIL B
EL 693·0
EL 690·0
6" DIA
EL 670·0
EL 736·0
2-1½"x1½" STEEL SUPPORTING ANGS
METAL GRATING ON PLATFORM SUPPORTED ON STEEL ANGS
2'-6" DIA STANDARD PIPE
½" WELDED JOINTS
DETAIL B
SECTION THROUGH STILLING WELL
2-1½"x1½"x¼" SUPPORTS
METAL PLATFORM
SECTION A-A



SECTION BB

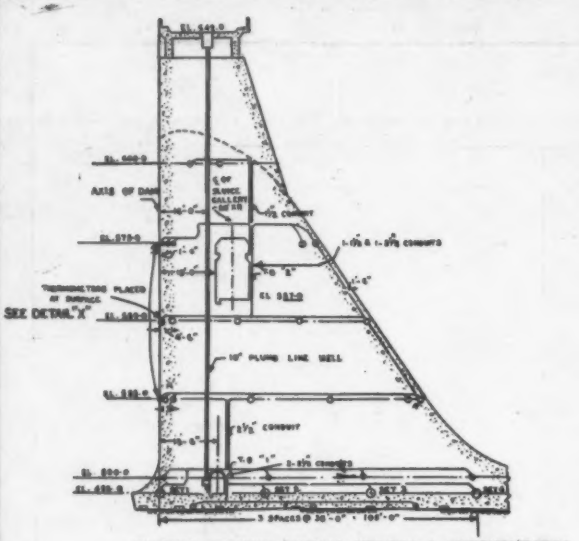


SECTION C.C.

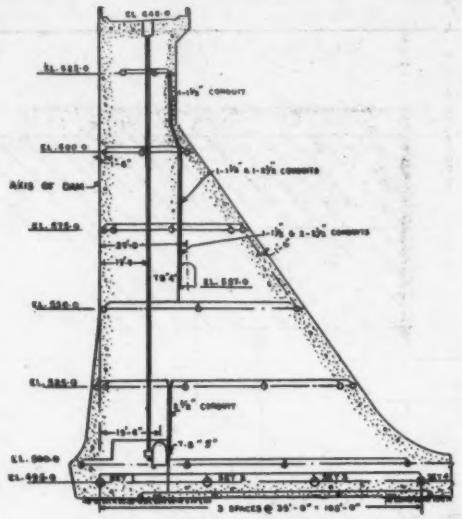


KEY PLAN

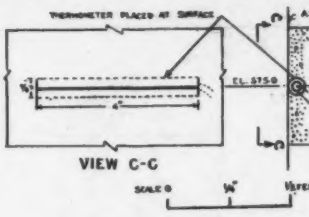
GOVERNMENT OF INDIA CENTRAL WATER & POWER COMMISSION	
HIRAKUD DAM MAIN DAM GAUGE WELL DETAILS - BLOCK 63	
DRAWN - S.P. GROVER TRACED - [illegible] CHECKED -	SUBMITTED - [illegible] RECOMMEND - [illegible] APPROVED -
	NEW DELHI DEC' 1966 — 100-IM-96



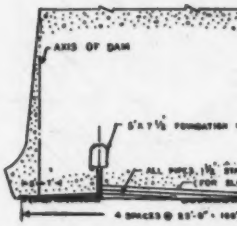
SECTION SHOWING STRAIN-METRES & THERMOMETRES
(BLOCK 35 STA. 145 + 70)



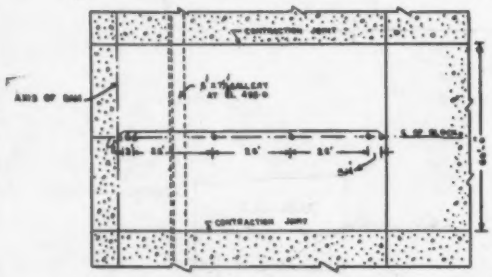
SECTION SHOWING STRAIN-METERS & THERMOMETERS
(BLOCK 57 STA 159 + 38)



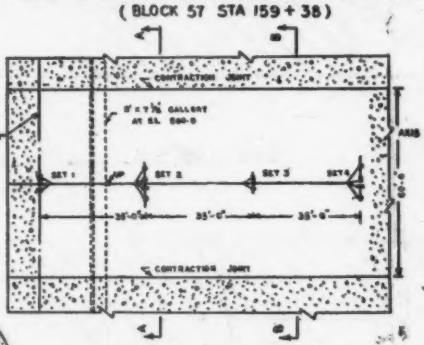
VIEW C-C



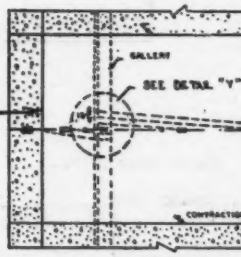
SECTION SHOWIN
(BLOCK



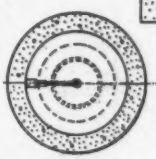
SECTIONAL PLAN AT EL. 525·0
(BLOCK 35)



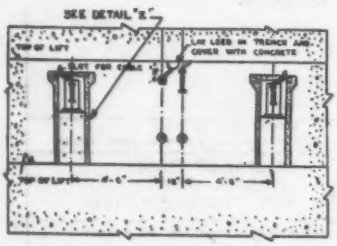
SECTIONAL PLAN AT EL. 495·0 SHOWING
STRAINMETERS (BLOCK 57 SHOWN-BLOCK 35 SIMILAR)



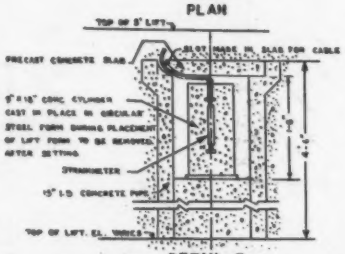
PLAN OF FOUNDATION SHOWING LOC
& THERMOMETERS (BLOCKS 57 SHO



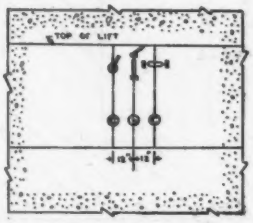
PLAN



SECTION A-A



DETAIL Z



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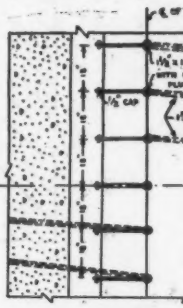
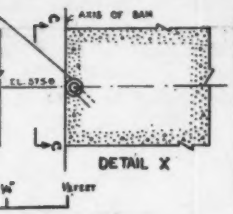
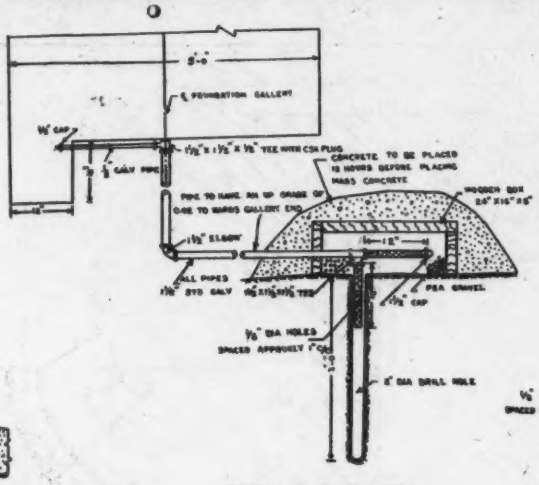


DETAIL Y

TRACED BY :-
COMPARED BY

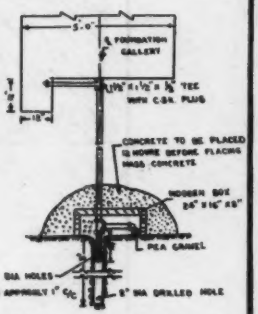
NO-STRESS STRAIN-METER INSTALLATION




5'-0"
℄ FOUNDATION GALLERY
CONCRETE TO BE PLACED 12 HOURS BEFORE PLACING MASS CONCRETE
WOODEN BOX 24" X 16" X 8"
PEA GRAVEL
⅛" DIA HOLES SPACED APPROXLY 1" C/C
8" DIA DRILL HOLE

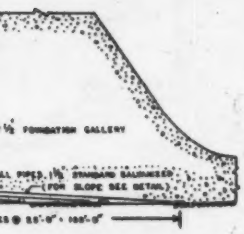
DETAIL OF UPLIFT CELL

SCALE 0 1 2 FEET

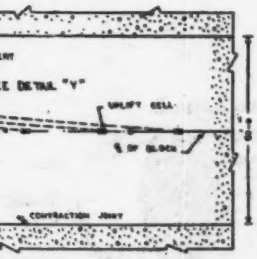

5'-0"
℄ FOUNDATION GALLERY
CONCRETE TO BE PLACED 12 HOURS BEFORE PLACING MASS CONCRETE
WOODEN BOX 24" X 16" X 8"
PEA GRAVEL
⅛" DIA HOLES SPACED APPROXLY 1" C/C
8" DIA DRILLED HOLE

DETAIL FOR CELL DIRECTLY UNDER THE GALLERY

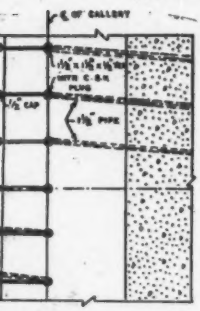
SCALE 0 2 4 FEET



ON SHOWING UPLIFT CELLS
(BLOCK 57



HOWING LOCATION OF UPLIFT CELLS
LOCKS 57 SHOWN, BLOCK 35 BASLAN)



SYMBOLS

T.B	TERMINAL BOARD
●	THERMOMETERS
⊕	GROUP OF STRAINMETERS
a	HORIZONTAL, NORMAL TO AXIS OF DAM
b	VERTICAL
c	HORIZONTAL, PARALLEL TO AXIS OF DAM

NOTE

ALL INSTRUMENTS HAVE 3 CONDUCTOR CABLES

ELEVATIONS AS GIVEN ARE TENTATIVE. ALL THERMOMETERS AND THE LENGTHS OF CABLE BETWEEN THE THERMOMETERS AND CONDUITS SHALL BE LAID IN 6" TRENCHES WHICH ARE TO BE IN FRESH CONCRETE AT THE TOP OF THE 5' LIFT AND THEN COVERED WITH CONCRETE TO THE TOP OF THE LIFT. GROUPS OF STRAINMETERS SHALL BE PLACED ON A PREPARED BED 12" BELOW TOP OF LIFT

THE DETAILED LAYOUT OF CONDUIT AND CONNECTIONS IS SUGGESTED. MODIFICATIONS DEPENDING ON FIELD CONDITIONS MAY BE MADE TO ACCOMPLISH THE SAME PURPOSE

PLUMBOBS AND JOINT-METERS TO BE INSTALLED AS SHOWN ON DRG. 100-R-26

REFERENCE DRGS.

1. 1.20-R-25 (GENERAL SPECIFICATION DRG)
2. 100-IM-23 (TERMINAL BOX DETAILS)

ITEM	QUANTITY
STRAIN-METERS	28 NOS
THERMOMETERS	28 NOS
3- CONDUCTOR CABLE	3500 FT
¾" CONDUIT	130 FT
½" CONDUIT	112 FT
1½" GALVANISED PIPE	220 FT
½" GALVANISED PIPE	15 FT
1½" x 1½" x 1½" TEE	12 NOS
1½" x 1½" x ½" TEE	12 NOS
1½" CAP	12 NOS
½" CAP	12 NOS
1½" ELBOW	10 NOS
30 METER TERMINAL BOARD	2 NOS
16 METER TERMINAL BOARD	2 NOS

SCALE 0 2 4 FEET

DETAIL Y

SCALE 0 3 6 FEET

DETAIL Z

SCALE 0 3 6 FEET

SECTION A-A & B-B

SCALE 0 20 40 FEET

OTHERS

GOVERNMENT OF INDIA
CENTRAL WATER & POWER COMMISSION

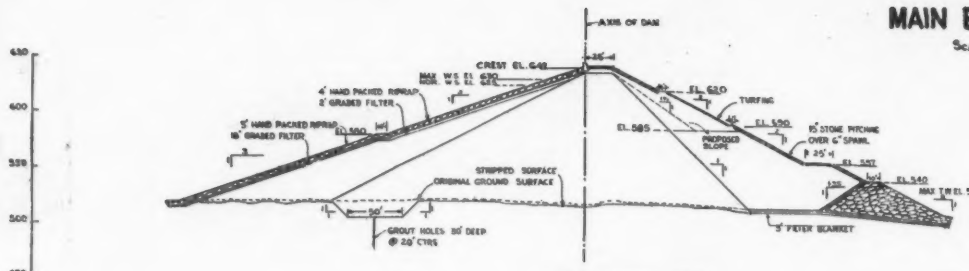
HIRAKUD DAM
MAIN DAM
INSTALLATION OF INSTRUMENTS IN CONCRETE DAM

DRAWN	N.C.R	SUBMITTED	K.C.THOMAS
TRACED	R.M.P.	RECOMMENDED	N.L.RAO
CHECKED		APPROVED	
		NEW DELHI MAY 1952	100-IM-22

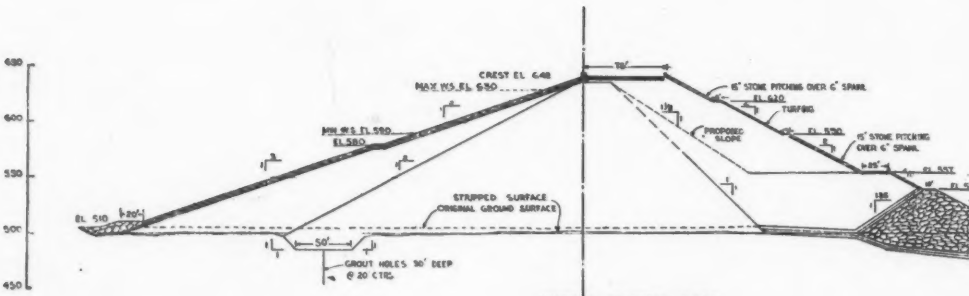
TYPICAL

MAIN E

Sc



LEFT EARTH DAM

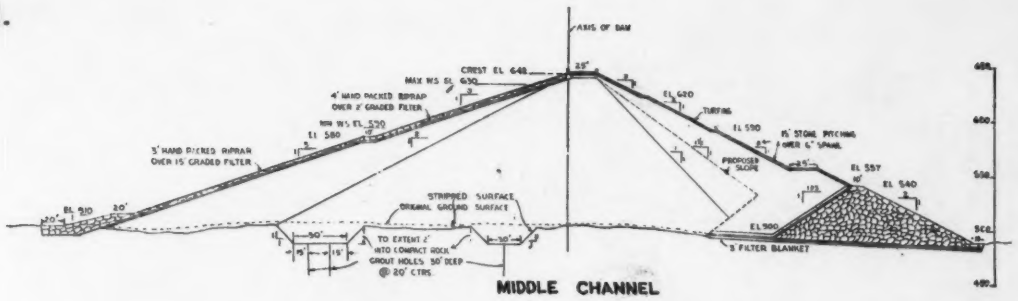


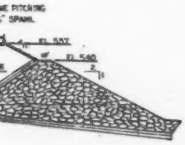
RIGHT EARTH DAM

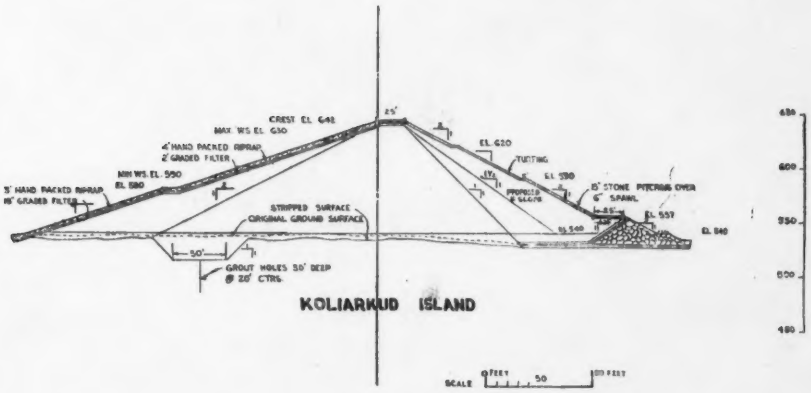
R.D. 7000

YPICAL SECTIONS OF MAIN EARTH DAM.

SCALE :- 50' = 1 INCH







SUPERINTENDING ENGINEER
NILAKUS DAM CIRCLE

PLATE II

openings are controlled by electrically operated gates.

Sluice Gates

There are 64 sluices, 40 in the Left Spillway and 24 in the Right Spillway. They are provided with vertical slide gates 12′×20.33′ each shutter weighing 26 tons. Weight of steel used in each gate including the embedded parts is 45.8 tons.

For operation of these gates, there are 5 Gantry cranes in the Left Spillway and 3 in the Right Spillway. Each gate is operated individually by these cranes. Each crane is 50 tons capacity. The hoisting speed of the gate is 1½′ per minute.

Emergency Gates

If any sluice gate goes out of order, 2 emergency gates in each Spillway are provided. The size of the gate is 16′ × 28.3′. Weight of each shutter is 44.6 tons operated by a 100 ton over-head crane from the top of the Dam. Weight of steel used in each gate including embedded parts is 307 tons.

Crest Gates

There are 34 bays over the Crest, 21 in Left Spillway and 13 in the Right. Each is provided with a radial gate 51′ × 20′ The weight of the leaf is 27 tons. Weight of steel used in each gate inclusive of embedded parts and trunnions is 45 tons.

Penstock Gates

The size of penstock gates on English units is 19.60 ft × 31.05 ft. and that on German Units 17.9ft.×30.68ft.

Draft Tube Gates

Size of gates on draft tubes in English units is 25′-6″×18′-1″ and that on German units 23′-7½″× 18′-5¾″.

Cranes for operation

There are 8 Gantry cranes for operation of sluice gates, 2 over-head cranes of 100 tons capacity for operation of emergency gates and penstock head gates and one gantry crane of 25 tons capacity for opearation of draft tube gates.

Gauge Well.

For elevation of water level in the reservior there is a gauge well in block 57 and a gauge well tower of R.C.C. constructed on the left flank wall, which will be fitted with automatic recorder with remote control to record water levels in the Reservior at each end.

Raw Water Intakes

Arrangement has been made to take raw water from the reservior for water supply on either side of the river and for the Hirakud Island. The raw water intake on either side of the river is 3′ diameter formed hole fitted with a valve, one at elevation 580 and the other at elevation 610. For water supply for the Hirakud island, one foot dia. formed hole with a valve is provided in the Left Transition of Right Spillway.

Installation of Instruments

There are two plumb bob wells, one at either end of the Dam, in left flank wall of the Left Spillway and block 57, running from the fundations upto the top of Dam for observation of deflection in the Dam, cells for measuring soil pressure and hydrostatic pressure on left flank wall, strain meters and thermometers in block 41 and 57 and uplift cells in blocks 58 and 59 are also provided.

Elevator Tower

There is an elevator tower with a lift in block 56 in the Power Dam for an adit leading to Power Plant at elevation 527 to 32.6 ft. above the top of the main Dam, connecting on the way galleries at elevation 557, 628 and top of the Dam. Between the elevator shaft and the slope of the Dam, there are seven rooms, one over the other, the roof of the top one being at elevation 674.63, i.e. 32.6, above the top of the Dam.

Junctions at Abutments

Proper care has been taken to key the concrete masonry Dam into the earth Dam and into the hill on the right side end. On the Left Spillway Dam, on the left end there is flank wall with training wall on the downstream. There are key ways at various places of the flank wall for proper bond with the earth Dam behind and obstruct creep. In continuation of the flank wall runs 100′ long cut-off wall keying into the earth Dam. On the right end runs 275′ long transition with 100′ long cut-off wall keying into the Earth Dam, training walls upstream and downstream. In the Right Spillway, on the left end runs similar transition 360′ long with 100′ long cut-off wall keying into the Earth Dam and Training walls upstream and downstream. On the right end, the Transition is 340 ft. long, keying into the hill. There was exploratory tunnel into the hill 26′ long at E.L. 618.5 which was filled with concrete and keyed into the masonry of the last block of the Dam. Proper care was taken to bond the masonry with the sides of the hill and grout the junctions at every 5′ lift.

Apart from that, earthen platform on the upstream 200 ft. long and 86 ft. wide has been constructed at the abutments with a layer of impervious earth on the hill slope and masonry pitching on the earth slope from river bed upto the top of the Dam.

Road Ways

The operation gallery in the Left Spillway is connected at either end with road along the rear of the Earth Dam at E.L. 557. That in the Right Spillway is connected at left end with road along the rear of Earth Dam at E.L. 557 and at the right end with masonry road in the body of the Power Dam at its rear at elevation 557.

On the top of the masonry concrete Dam runs a 25′ road with kerbs and ornamental parapets with lamp posts on the downstream parapet.

Power House

The work in the Power House was a colossal job with such deep foundations, 71′ below the river bed, bad foundation rock in the first two units and heavy subsoil water trouble, huge quantity of excavation, complicated nature of work which is mostly reinforced cement concrete with various blockouts and with special treatment for joints. The height of the structure from the foundations to the top is as high as 148′. All the four present units and House Service unit are completed. Also, of the 3 units for future extensions, excavation for foundation has been completed. In Units 5 and 6 bed concrete has been put in

and the draft tubes are completed and the structure raised to transformer deck level. Opposite to unit 7, cellular coffer dam is built in line with the downstream wall of the transformer deck. The draft tubes of units 5 and 6 will be closed with gates. With this arrangement, work in the future units can be carried out without difficulty with the water in the Tail Race.

In the Power House, there are two floors, one running at elevation 510 called turbine floor and the other at elevation 527 called genertator floor. Behind the units 2 and 3, there is an oil room with floor level at 507.5 and roof at elevation 527. Between the Power House and the Power Dam, there are auxiliary rooms in triple storey structure with a lift, containing cable room, battery room, control room, shift engineers room, ventilation room, reception room, recreation room, store room, toilet room, telephone exchange etc., The whole Power House and auxiliary rooms are air conditioned.

The entire work of the Power House has been completed in three seasons.

The Turbines will discharge water through draft tubes into the Tail Race. This disposed off water taken in Power Channel will generate power again at the lower Power House 17 miles below.

EARTH DAM

This is of zoned rolled fill type with filter and rip-rap on the upstream slope and filter and rock fill toe at the downstream.

Section of the Dam

It has got 25′ top width with 3 : 1 slope on the upstream and 2: 1 slope on the downstream. The upstream semi-pervious zone is from 3 : 1 upstream slope to 2 : 1 upstream slope and the downstream semi-pervious zone is from 1 : 1 or 1½ : 1 downstream slope to 2 : 1 downstream slope. Between the two is the impervious zone. There is cut-off trench in the impervious zone at the junction of upstream semi-pervious zone. Filter blanket at the base of downstream semi-pervious zone and rock fill at the toe, with a longitudinal toe drain. The upstream slope has 3 to 4 ft. thick rip-rap with 18″ to 2 ft. filter underneath. On the doustream slope, above the rock fill, there is stone pitching and cement concrete slab in part height, c.c. slab pitching in the top portion and turfing in between. The idea of cut-off trench is to cut-off seepage at and below the base of the Dam. The object of upstream semi and rip-rap with filter underneath it, is to drain off water and give better stability. The rip-rap is also protection against wave wash. The object of filter blanket and rock fill toe is to pass seepage water at the base, if any, without disturbing the upper earth. The idea of downstream semi-pervious zone is to drain of percolation water, if any seeps through the impervious zone. The rockfill and semi-pervious zone give better stability.

Rear slope of Earth Dam.

Location

It stretches from hill on the left side to the left edge of the left channel, over part width of the left channel and covering the deep channel, over the entire middle channel and part width of the right channel. Special care had to be taken in preparing foundations in the river bed, which was full of boulders with pervious zones here and there.

Foundation

The base for the Dam was cleared of all jungles, roots, boulders or loose rock, ant holes, rat holes and top soil was removed. There were lot of white ant hills in the Hirakud Island portion. Pits were dug to remove such hills completely together with the main hill with queen ant. Such pits were given 1 : 2 side slopes and filled with impervious earth with optimum moisture and well tamped.

In the impervious zone, where there was pervious or semi-pervious soil, it was removed till impervious layer was reached. In case of middle channel, there were some crevices in the hard granite rock in the impervious zone, which were grouted with impervious clay. All the rocky surfaces were roughned for proper bond. Similarly in upstream semi-pervious zone, where there was pervious soil, it was removed till semi-pervious or impervious layer was reached. The base of downstream semi-pervious zone where filter blanket was laid was cleared of all loose materials and slope for drainage towards the downstream toe was taken into consideration while designing and aligning the filter bed.

Cut off Trench

50′ wide cut-off trench dug to rock or impervious strata under the seat of the Dam in the impervious zone at its upstream junction runs from one end to the other. In case of deep channel, width of cut-off trench was kept 100′. In case of middle channel, two cut-off trenches one 50′ wide and the other 30′ wide were provided.

The trench was dug 2 ft. into the impervious soil or into the hard rock.

Detailed cores were taken along the cut-off trench to fix the level to which it had to be excavated. Care was taken to see that there was no pervious or semi-pervious or shattered zone down below. Undisturbed samples of base materials of the trench were taken and tested in the laboratory to determine the permeability. While digging the cut-off trench, sandy layer across the Dam was found at some places, which was found stretched from the axis to the downstream toe. Such layer was removed right through and refilled with impervious material under optimum moisture tamped or rolled to specified density. Where the bed of the trench rested on impervious material, no grouting was

EXCAVATORS

RB FOR PREFERENCE

One of the three largest excavators operating in India

Serving on the HIRAKUD DAM Project were
TWO 5-W RUSTON BUCYRUS WALKING DRAGLINES
TWO 54-R-B RUSTON BUCYRUS SHOVELS
THREE 15-B BUCYRUS ERIE SHOVELS & CRANES

Names which mean delivery when promised.

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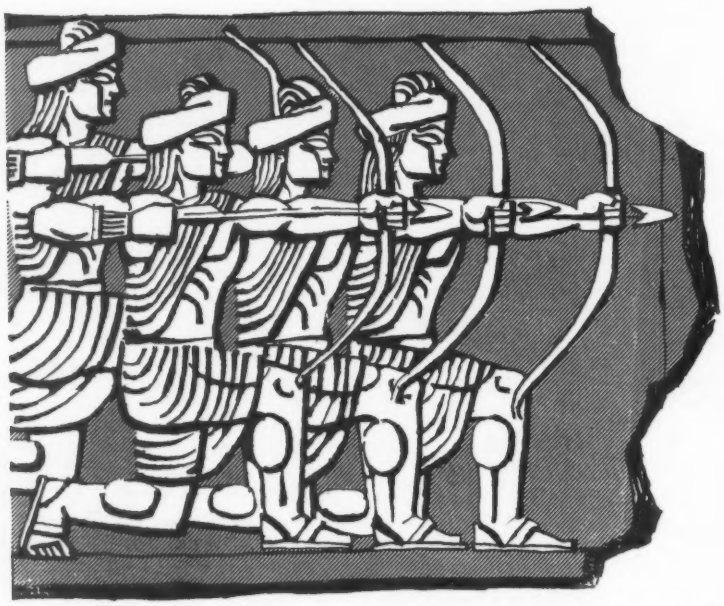
Surprise at Thermopylae

When Xerxes, the mighty Persian emperor, invaded Greece in 480 B.C. he had with him a company of Indian archers. These Indian archers used a new weapon—a steel-tipped arrow which had been brought all the way from India. History records that the Greek army was surprised by the superior arms of Xerxes and was defeated in the battle of Thermopylae.



Today, once again, steel is very much to the fore in the nation's thinking, but with a different intent. The country's steel-making capacity is being rapidly enlarged, not for purposes of war, but for peace and development.

TATA STEEL SERVES THE NATION

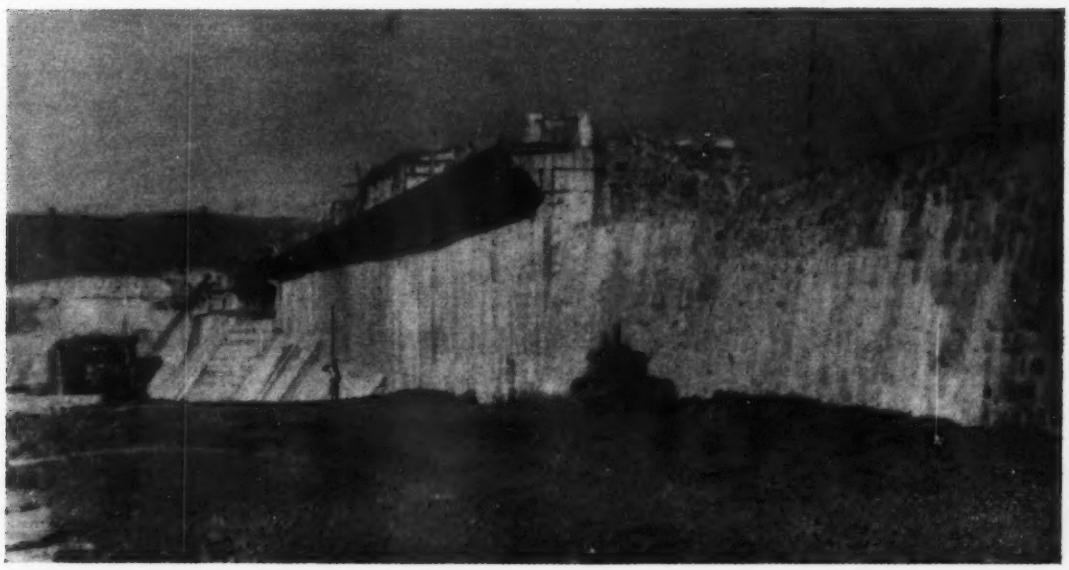
A shovel loading a rear dumper

done, the trench was filled with specially selected impervious clayey materials watered and rolled in 6″ layers. Where rock was met with, it was dug at least 2′ into solid hard rock and grouted. Ordinarily one row of holes 30′ deep 20′ centres along the centre line of the trench was drilled and grouted, but where nature of geological strata warranted closer holes and even in full width, it was done so to consolidate the foundations properly. In the case of cut-off trench in the deep channel bed, two rows of holes were drilled and in middle channel, two rows of holes were drilled in the main cut-off trench and one row in the additional one. All the veins and crushed zones were properly cleared to the required depth and grouted.

The nature of geological data in the cut-off trench under the Earth Dam was as under :—

500 *to* 1100 (*the left abutment*). This zone consisted of weathered granitic gneiss with an exposure of block gneiss. This was grouted.

Compaction by Tractor at the Transitions



Earthwork on left earth dam by rear dumpers

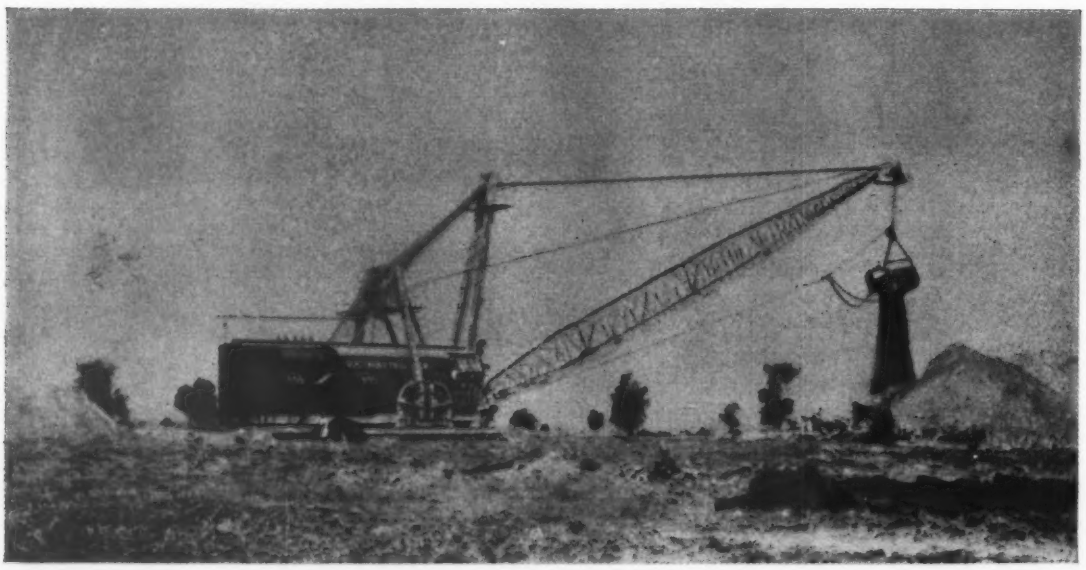
1100 *to* 2000. The bed of the trench was carried 2 to 3′ into disintegrated rock which was found to be compact and impervious, and extended to a considerable depth. No grouting was necessary.

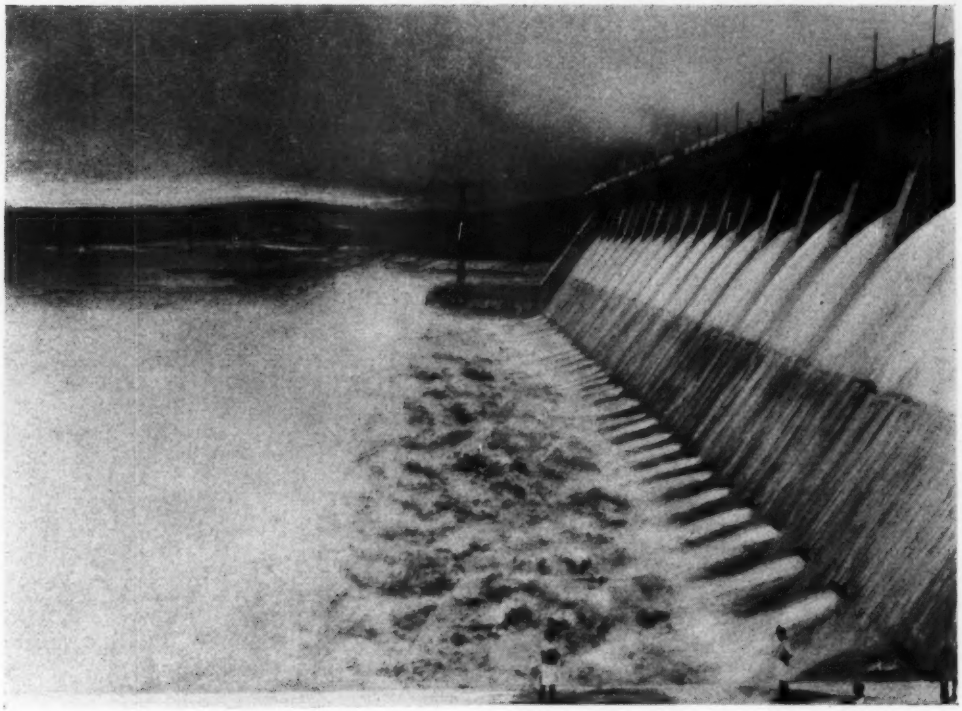
2000 *to* 2400. The excavation was taken to hard rock which was grouted. There were fault zones in which additional holes were drilled and grouted.

2400 *to* 4827. The bed of the trench consisted of gneiss with bonds of schist running in between. The principal system of jointing and the strike was parallel to the river "N 70°W" and dipping "S 65°W". This section took lot of cement. The average intake comes to 12.83 bags per linear foot. One hole 30′ deep took as many as 1390.75 bags of cement, which was the maximum grout consumption in the entire Dam foundations.

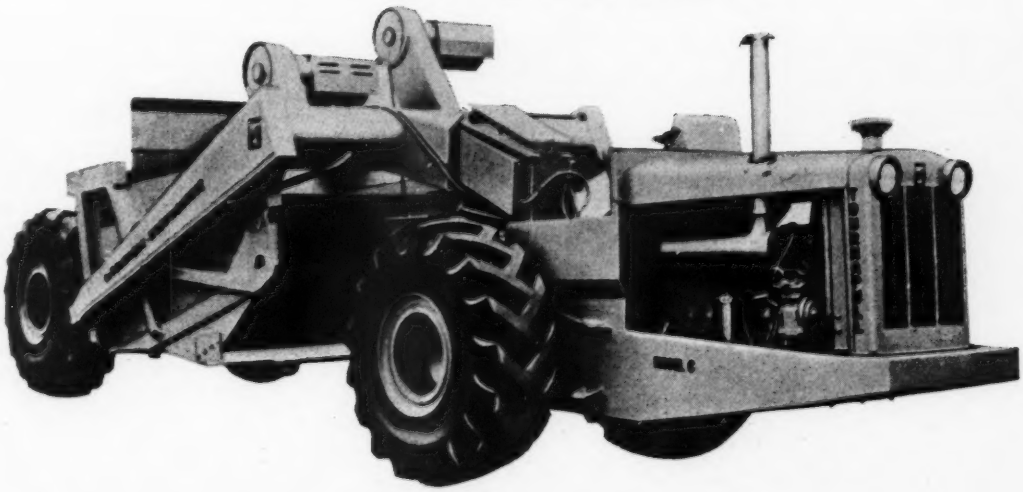
R.D. 6690 *to* 7270. The predominant rock was granitic gneiss. The principal system of jointing was parallel to the river "N 65°W" and dipping "S 62°W".

The huge Walking Dragline at work





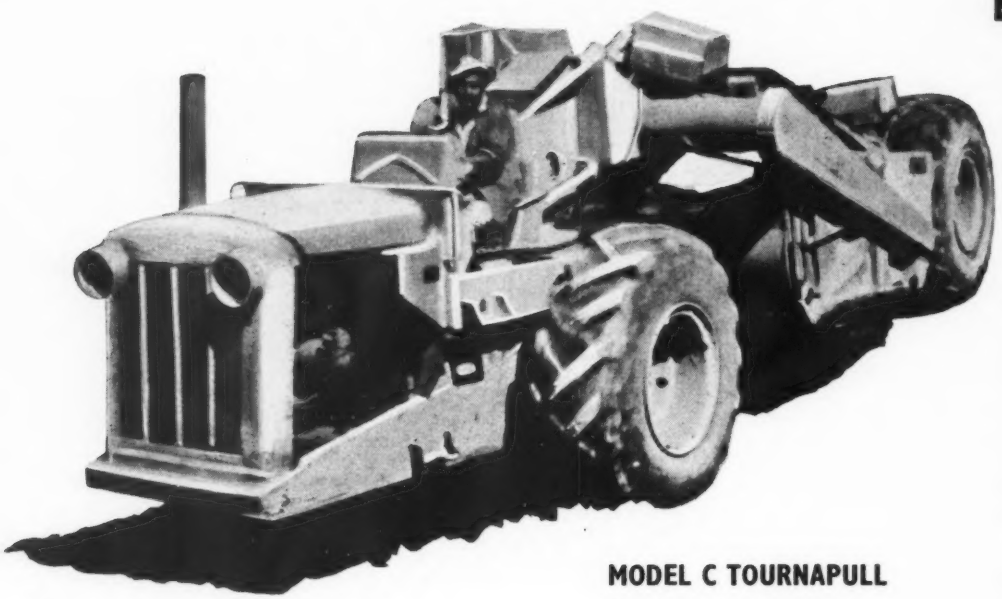
LeTOURNEAU-WESTINGHOUSE
earth-moving equipment



at HIRAKUD DAM

WJC-268

LeTOURNEAU-WESTINGHOUSE

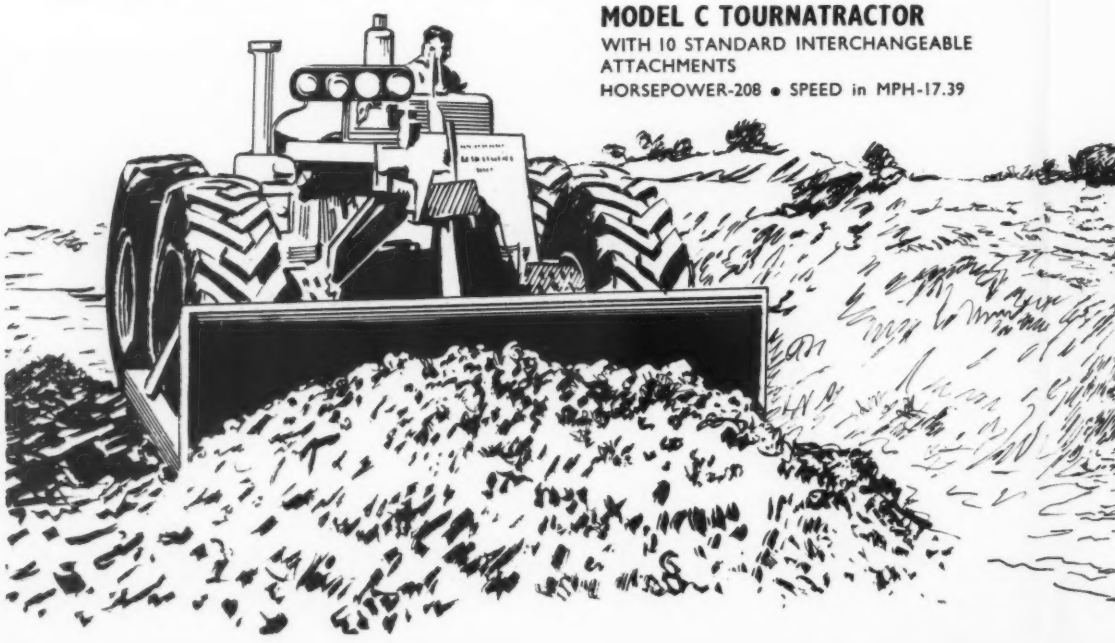


MODEL C TOURNAPULL

WITH MODEL C SCRAPER
CAPACITY: Cu. yds—Heaped 16 • Struck 12.2

MODEL C TOURNATRACTOR

WITH 10 STANDARD INTERCHANGEABLE ATTACHMENTS
HORSEPOWER-208 • SPEED in MPH-17.39



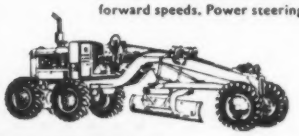
USE earth-moving equipment

L-TOURNEAU LET WESTINGHOUSE

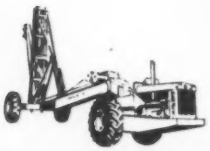
In 1949, when the work started at Hirakud Dam, 30 LeTourneau Earthmoving machines went into operation. Jungle clearing, levelling, road making and many other jobs were done by these machines. Later on 15 more electrically controlled Tournapull Scrapers were added to the existing fleet to cope with the vast construction work. These LeTourneau machines, following a tradition of service already set in the other huge undertakings throughout the world, have moved many millions cu. ft. of earth quickly and economically. LeTourneau Fleet at Hirakud Dam, consisted of :—**17 'C' Tournapull Scrapers of 16 cu. yd. capacity. 10 high speed rubber-tyred Tournatractors with Bulldozer attachment. 18 Super 'C' Tournapull with Tournatrailer plus many scrapers and dozers.**

WJC-268

ADAMS MOTOR GRADERS: powered by 60 H.P. to 150 H.P. diesel engine. 8 forward speeds. Power steering.



MOBILE DIESEL CRANES: 10, 20 & 30 tons capacity.



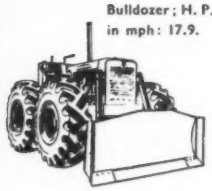
MOTORISED SCRAPERS: from 7.5 to 25 cu. yds. heaped capacity. Electrical controls, low turning radius.

MODEL C BOTTOM DUMP with Model C Tournapull.

REAR & BOTTOM DUMPS: Rear Dumps 11 to 35 tons capacity and Bottom Dumps 18 tons capacity. Interchangeable Trailing Units.

MODEL C TOURNATRACTOR: with 10 standard interchangeable attachments, viz. Bull Dozer, Angle Dozer, Root Rake, Snow Plough, etc.

LW 16 TRACTOR: with hydraulic Bulldozer; H. P. 111. Speed in mph: 17.9.



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WJC-26B

This channel took grout at the rate of 3.01 bags per linear foot.

7270 *to* 7565. This covered the deep channel, the gorge section. It consisted of schist. It had a narrow shear zone with a width of 1′ to 2′. Seepage was observed through this, which was arrested by grouting.

7565 *to* 8100. It consisted of disintegrated rock. It was hard disintegrated rock and well compact. It did not take much grout.

8100 *to* 9450. In this reach good compact and impervious disintegrated rock was met with. Bed of the trench was taken to 2 to 3′ into the D. R. and no grouting was found necessary.

9450 *to* 12000. This consisted of open jointed rocks with quartz veins, hence it was drilled and grouted.

12000 *to* 13000. *Middle channel section.* There was scattered rock in 100 ft. length on either side of the middle channel which took heavy grout. In the bed of the middle channel 5 to 8 ft. excavation had to be done to get at good rock. In one portion 60′ in length there was crushed zone, where the excavation had to be taken 20′ deeper.

Additional cut-off trench in Kolarikud Island, R.D. 13000 *to* 14000. The soil under the base of the Dam in this reach was light consisting of admixture of sand and silt. Therefore, an additional cut-off trench 10 ft. wide was dug along the downstream toe of the impervious zone and taken to compact soil below. The depth of excavation varied from 10 to 15′. This was filled up with good impervious clay and compacted in 4″ to 6″ layers.

On the upstream side beyond the upstream toe of the Dam, a trench 30′ wide and 3′ deep was dug and filled with impervious soil well compacted to serve as upstream impervious blanket.

After the base was grouted, it was cleared properly. Before starting the first layer of impervious, selected clayey material, the rock surfaces were roughened and covered with mud slurry to bond with the clayey layer. All the depressions were first filled with baskets by manual labour in layers of 4″ and tamped with pneumatic rammers till the surface became even for the dozers to spread the earth in even layers.

Borrow Areas

Borrow areas for each kind of soil—impervious, upstream semi and downstream semi were selected after laboratory tests for permeability and density on the samples. Depths of cut were controlled according to the nature of the soil. One laboratory inspector always remained in each borrow area during the course of the work.

The borrow areas were stripped properly till all the roots of vegetation and loose or unapproved soil were removed. In the case of the loader area, borrow area was watered wherever and whenever it was dry. In case of shovels, and scrapers, it was not found necessary.

Optimum Moisture

The moisture was controlled at the dumping place. Required quantity of water was added to each dumper load before it was spread. The moisture content varied with each borrow area and the time and the season.

The standard density for every soil was determined by Proctor's compaction test in the laboratory and maximum density was found out at optimum moisture content.

Compaction

Each layer of earth, which was spread to 9″ thick was compacted with sheep-foot rollers to the specified density.

There were field laboratories and density of each layer in various sections and various places was taken at the rate of about one sample for 4,000 cft. of earth work. After the layer was passed by the laboratory then alone another layer was received. The densities of compacted earth were as under :

Semi-pervious.	Dry density.	116 to 125 lbs/cft.
	Wet density.	130 to 140 lbs/cft.
Impervious.	Dry density.	105 to 110 lbs/cft.
	Wet density	125 to 130 lbs/cft.

Compaction was done by sheet foot rollers. In depressions in the founations, at the junction of masonry structures or sides of cut-off trench, compaction was done by Pneumatic rammers in which case thickness of layer was kept 4″. Chain rolling by Fowlers and Tractors was also done along junctions of masonry structures and sides of cut-off trench.

Drainage of seepage water through the Dam

Filter.

After clearing the foundations, bed filter in downstream semi-pervious zone was provided for proper drainage of seepage water. Cross slope 1 in 50 was given to lead into the longitudinal toe drain, which was connected with natural drains. Similarly it was provided on upstream face of the rock fill and under the upstream rip-rap.

The filter materials used were laid in two layers. The gradation of each filter layer was kept to met the requirements with respect to the material to be protected and also with respect to the adjacent filter layers. This was found out in the laboratory on the basis of mechanical analysis. The following gradation was kept.

(*a*) For filter material in contact with foundation or earth fill materials.	Well graded coarse sand and gravel passing through 1/2″ screen.
(*b*) For the middle layer of the filter blanket and layers in contact with rock fill	Coarse rivers shingle passing through 3″ screen and retained on ¼″ screen.

In the semi-pervious zone over the virgin soil, one foot of sand, over that one foot of shingle and then one foot of sand as provided as bed filter. Where there was rocky surface shingle was laid directly over rock and over that one foot layer of sand.

Over the filter, the first two layers of semi-pervious soil were laid by manual labour, watered and com-

Compacting by sheepfoot rollers.

pacted with rammers by manual labour, so that the filter may not be disturbed.

Over the upstream slope of the Dam and under the rip-rap was laid 9″ to one foot layer of coarse sand, then 9″ to one ft. layer of river shingle graded from 1/2″ to 3″. Over the rock fill at the downstream toe, one ft. layer of river shingle graded from 3″ to ½″ and 1ft. layer of sand was placed before putting layer of semi-pervious soil.

Compaction by pneumatic tampers

Rock Fill.

It is placed at the downstream tow. It has got 10 ft. top width, 2 : 1 slope on the outside and 1: 1 slope on the inside, with a toe drain 10′×4′ at the downstream of it. At the base of rock fill is filter with 12″ shingle and 12″ layer of sand underneath it. On the inside slope of the rock fill is 1 ft. layer of shingle and 1 ft. layer of sand over it.

Rip-Rap. It is placed on the upstream slope. It is 3 ft. thick upto elevation 580 (i.e. 10 below dead storage level) with 9″layer of shingle and 9″ layer of sand underneath it. Above elevation 580, it is 4′ thick with 12″ layer of shingle and 12″ layer of sand underneath.

Pitching and Turfing.

Above rock fill, the downstream slope is pitched with stone 15″ thick with 6″ quarry spawls underneath upto elevation 590 in case of Left Earth Dam and upto 557 in the case of Right Earth Dam. The slope from 557 to 570 on Right Earth Dam and the top 8′ sloping length is pitched with C.C. slabs 4″ thick. In between, the whole slope is turfed except the 5′ beams at elevation 590 and 620, which are paved.

Drainage.

There are water sprouts in the roadway in the upstream parapet and downstream kerb wall. On the downstream they discharge into cross C.C. Drains. The berms at elevation 590 and 620 are use as longitudinal drains by constructing kerb on the outside. Through these are taken the cross drains discharging into longitudinal drains along the road at elevation 557, underneath the road again and along the slope of the Dam upto the toe, discharging into the toe drain.

Bonding at deep channels

In the case of deep channel, and middle channel, the sides of the channels were cleared properly as stated for bed foundations. Then, benches were made. Height of each beach was of thickness of a layer. In

middle channel side slopes one key was dug into the slope in the upstream semi-pervious, one in the impervious zone and one in the down-stream semi-pervious zone. Apart from that the two cut-off trenches were taken well into the Island on either side.

End Protection.

The Earth Dam at the Left abutment keys into the hill. The cut-off trench is carried 100 feet into the hill and filled with impervious clay properly compacted. Apart from that the upstream slope of the hill for 100 ft. length at the junction is pitched with masonry.

Parapets and Roadway.

The parapet is built on the upstream with one foot thick and 4′ wide concrete base and 4′ high masonry foundations. The parapet is of masonry 2′ wide and 3.63′ high including coping with plasters. On the downstream is built kerb wall in cement concrete blocks, 1′ above road level.

The road is 25′ wide with 6″ soling and 4½″ metalling, over which 6″ C.C. slab will be laid.

Architectural Features

At the left abutment faces a nice pavilion and a gateway with Konarak wheel prepared from the local granite gneiss stone.

Installation of test apparatus

General Function :

The installation of the testing apparatus has been found essential for the determination of the behaviour of the earth dam during and after construction. These installations can be mainly divided into two categories. (*i*) Piezometer installation to observe the pore water pressures existing in the foundation and the embankment and (*ii*) Settlement apparatus to measure the consolidation, vertical and horizontal movements of the Earth Dam.

Here four types of apparatus are installed (1) Piezometer installation (2) Cross Arm installation (3) Base plate installation and (4) Surface movement point installation.

Location.

(1) Piezometer Installation.	R.D. 4910, 7240, 9510 and 12230 cross sections.
(2) Cross Arm Installation.	R.D. 7250-20 U.S. and 28.7 DS & RD. 9500-35 D.S.
(3) Base Plate Installation.	R. 9500-20 U.S., R.D. 10000-20 U.S. & R.D. 13400-20 US. of Axis.
(4) Surface movement points.	R.D. 7000 to R.D. 7500 U.S. and D.S. slopes.

Piezometer Installation

The piezometer installation helps in recording the pore pressure variations in the foundations and embankment of the earth dam by means of (*a*) Foundation type piezometer tip and (*b*) Embankment type piezometer tip respectively connected to a central observation well fitted with necessary valves and gauges through plastic tubing.

The information obtained from them is helpful not only in determining the safety and performance of the structure but also in the future design of Earth Dams.

(*a*) *Foundation Type Piezometer tip*

This tip is used to measure pore water pressure through a pipe extending vertically downwards into the foundation. This is moulded by the fabricator with 7/8 inch dia by 1/4 inch alundum disc sealed in place and two plastic tubes are cemented to the body. Below the porous disc, the section is extended to form a coupling.

(*b*) *Embankment type piezometer tip.* This tip is used, with disc down, at any point in the embankment where pore water pressure observations are desired. This is moulded same as the foundation type except that the extension below the porous disc is not required. The porous disc will come in contact directly with the clay.

Process of installation of the apparatus

To avoid interfering with embankment placing operations, all the tip and tubes are carried in the trenches. To carry the tubes one main trench is excavated, but for connecting the tips off set trenches are made at right angles to the Main trench at the proper locations. These tenches are kept on level grades, or on ascending or descending grades, relative to the entrance pipe into the terminal well. This process is strictly followed to avoid air getting trapped inside the piezometer lines.

After the trenches are excavated and levelled, a two inch protective cushion of selected fine material typical of the adjacent embankment in the bottom of the trench has been compacted for laying the tubes of the piezometer tips.

At the time of back filling care is to be exercised to prevent injury to the tubing. Individual tubes are separated at least ½ inch. The tubes are to be numbered for identifying the location of the tips. Three inch of selected fine materials is compacted over the tubings and then the adjacent embankment material is to be compacted in 4-inch layers.

Terminal Well.

These wells are constructed of reinforced cement for installing the terminal well apparaturs to take pore pressure readings. These are designed for 40 to 60 tips. As soon as the apparatus are fitted inside the wells, the piezometer tips are put into operation to record construction pressures as embankment placing operations progress. This foundation and embankment pressure is transmitted from the piezometer tip through the liquid filled tubes and observed on the compound gauges mounted in the terminal well.

Cross Arm Installation

This sort of installation is provided for measuring the consolidation within the embankment, settlement of foundation and seepage through the embankment. These cross arms are of 5-foot intervals.

This installation consists of (*a*) base section (*b*) cross arm section and (*c*) intermediate section.

(*a*) *Base Section.* A 2-inch iron pipe 7-6″ long is embedded below the foundation in which a latching plate is provided in the lower 2-foot section for catching the torpeds at the end of cross arm readings.

[*Continued on page* 52

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Dykes in Hirakud

By

DR. R. P. VERMA D.I.C., M.Sc. (Lond.), D.Sc. (M.I.T).

Superintending Engineer,
Dykes, Design and Investigation Circle, Hirakud Dam Project

The Hirakud Dam Project involved construction of 13 miles of Dykes in total length. The Right Dyke is one stretch of 35,500 ft. and the Left Dyke is made up of five gaps. The following contribution gives an idea of the design features and construction methods of the Dykes. In particular the Right Dyke involved such a great volume of earthwork that mechanical equipments had inevitably to be brought into use. Although dyke construction in India is not at all novel, the experience of Hirakud may be read with great interest.

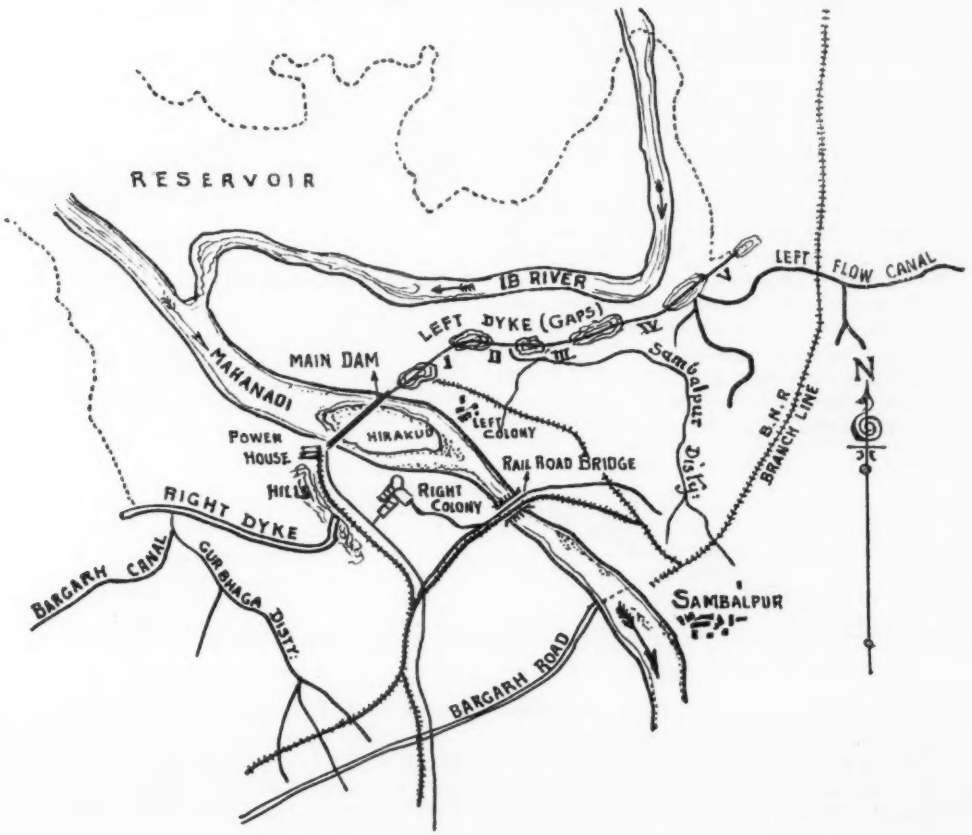
The Hirakud Dam Project is being executed by the Government of India, Ministry of Irrigation and Power in the State of Orissa. The Orissa State is richly endowed with natural resources, fertile land, extensive and variegated forests, and abundance of mineral wealth beneath the soil. To exploit these gifts of nature, it is necessary to have cheap power and irrigation facilities. With this end in view, it is proposed to make use of the waters of the Mahanadi that courses through the heart of this State for over 300 miles draining an area of 51,000 square miles before it empties itself into the Bay of Bengal.

The Main Dam is about 3 miles in length. There are dykes on the right and left sides to close the gaps in the hills for a total length of about 13 miles.

The dyke on the right side called the Right Dyke is in one stretch of 35,500 feet but that on the left is made up of five gaps connected together by a link road at almost the same level as the top of the Dam, so that when the Dam and the dykes are completed, it will result into a continuous pleasant drive of 22 miles from one end to the other.

The main canal of the Hirakud Project with a

Fig. 1—Location of the Dam and Dykes.



discharge of 4,800 cusecs takes off from the right dyke. A smaller canal, the Sason Canal, with a discharge of 630 cusecs takes off from the left dyke in gap IV. There is yet another small canal which takes off from the left dyke, but its capacity is only 120 cusecs.

The longitudinal section of the dykes as compared with that of the dam is shown in Figure 2.

An earth dam designed and built to satisfy these criteria will obviously prove to be as durable and permanent a structure as any other work of man can be.

The earth dykes of the Hirakud Dam have been designed with a slope of 1 : 3 on the upstream side and 1 : 2 on downstream side. The upstream slope is protected with a layer of 6 inches of sand laid against

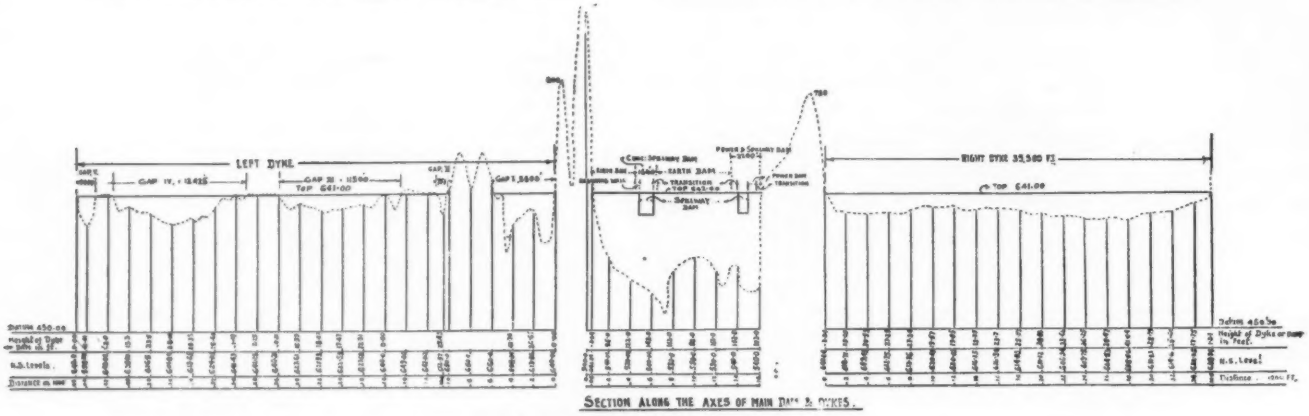


Fig. 2— Longitudinal Section.

All these dykes are of earth roll-filled type, excepting the 2nd gap in the left dyke which comprises a stone masonry section over a small stretch.

Principle of design

The practical criteria for the design of earth embankments forming a dam may be summarised as follows :—

(*i*) The discharge capacity of the undersluices and spillways should be great enough so as to eliminate all chances of overtopping.

The line of saturation should be well within the downstream toe.

(*iii*) The upstream and downstream slopes must be so constructed that for the particular material used in the construction they will be stable under all conditions.

(*iv*) There must be no opportunity for free passage of water through the embankment.

(*v*) Water which seeps through and under the embankment must have a velocity at the point where it rises to the surface so small as to be incapable of moving any material of the embankment or of the foundation.

(*vi*) The free board must provide enough safeguard against overtopping by wave action.

the compacted earth slope. A layer of 6 inches of graded filter is laid over the layer of sand which in its turn is covered by 2½ feet of rubble pitching. On the downstream side, a rock toe is provided as shown in figure 3.

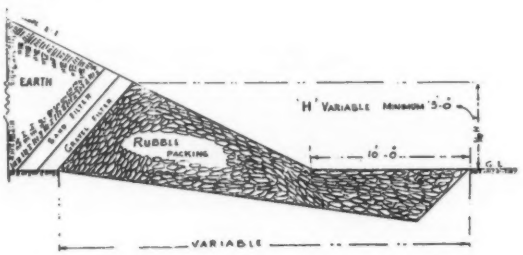


Fig. 3— Rock toe on the downstream of the Dykes.

The height of the downstream toe is kept at H/10 or 5 feet whichever is higher in portions where the dyke is 20 ft. or above. Where the height is less than 20 ft. the toe is reduced to 3 ft. in height. A layer of sand and graded filter is provided on the earth side of the toe.

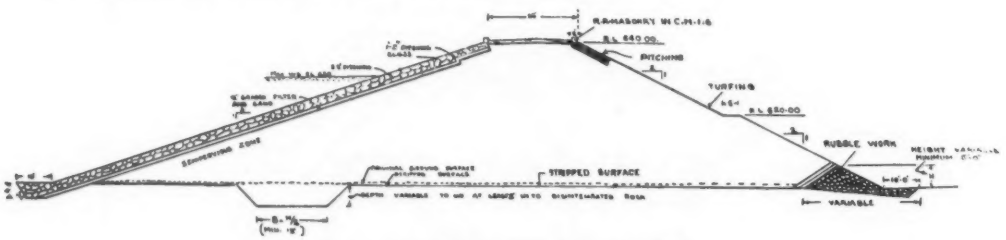


Fig. 4— A typical cross-section of the Dyke.

It is filled up with impervious soil properly rolled and is meant to cut off any passage of water which may adversely affect the stability of the dyke. On the downstream side, 1'-6" thick pitching is being

provided upto a depth of 5 ft. from the top. A typical cross section of the dyke is given in Fig. 4.

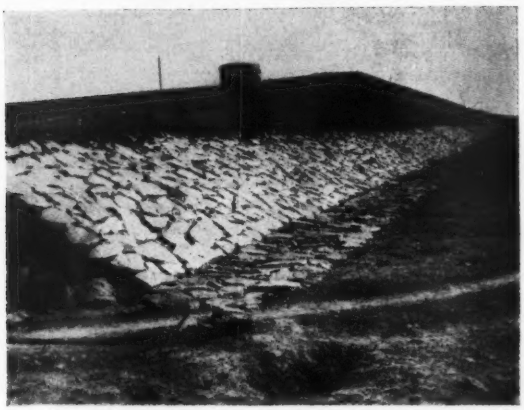


Fig.5— A view of the downstream toe.

The selection of site for the dykes has been done after elaborate survey work. These dykes run mostly over ridges, so that the maximum storage is assured with the least amount of work involved in the construction. Situation of the borrow areas required for the particular type of soil was also taken into due consideration in making the selection. The borrow areas were thoroughly investigated as to the availability of the soil required for the embankments. They were generally located on the upstream side of the dykes as the land there will ultimately be submerged in the reservoir.

Construction features

An entirely safe and substantial design can be completely ruined by careless and inefficient execution. Hence a careful attention to every detail of construction is as important as the design itself. This was the principle faithfully observed at all stages of construction. The area under the seat of the dyke was cleared of all the jungles and shrubs, stripped of all vegetation and the roots were taken out. All loose rocks were removed and so also the top layer of soil to a depth of 6 inches or more, depending on roots and vegetation and nature of soil so that the embankment could be laid on firm foundation. In order to ensure complete bond between the superstructure and the foundation the prepared base was ploughed and disc harrowed. Earth brought from the borrow areas was placed in layers of 9 inches to 12 inches and water was sprinkled over each layer in order to achieve the desired water content in the mass of earth laid. The earth was then rolled with sheepsfoot rollers drawn by tractors The sheepsfoot rollers were filled with sand so as to exert a pressure of 200 lbs. per sq. inch. It was observed that the passage of sheepsfoot rollers about 16 to 20 times compacted the earth almost to the highest possible dry density. Layer by layer the earth was laid to a premarked profile, watered and rolled. The slopes were then dressed to proper shape before the operation of laying the protective layers of sand, graded filter and rubble pitching was carried out.

Field control of moisture content and compaction was exercised by a batch of Analysts and Embankment Inspectors who took samples and performed tests on them in the Field Laboratories located at the work site. Field tests were conducted as the work went on and the results obtained were tabulated and correlated then and there and corrections applied either for purposes of compaction or for those of moisture variation at every stage of the work.

The rubble pitching work consisted of one man stones laid on edge over a lower layer of spalls. The material for this work was selected as to size and shape to secure fairly large-flat-surfaced stones which were laid up with an even surface and a minimum of voids. They are placed compactly with broken joints and so matched and interlocked that they were keyed together with a minimum of joint space.

The top of the dykes and the link roads are being provided with a 16 ft. metalled chip carpetted roadway. On the downstream side, paved drains have been constructed to drain out the rain water.

Right Dyke

The Right Dyke starts at a distance of about 3½ miles from the right abutment of the Main Dam and connects the hill of the right abutment to another range of hills in far north. It is a single stretch of 35,500 ft. passing over suitable ridges between the two hills so as to result into a minimum of embankment. The average height of the dyke is 29.8 ft. and the maximum 44 ft. The quantities of the different items of work involved are given in table 1. The total estimated cost of this work is Rs. 1,71,56,400/-. This dyke is being constructed under one single contract, the largest in the Hirakud Dam Project and is settled at Rs. 1,11,60,000/-. This does not include the compaction of the embankment and the turfing on the downstream slope which are done departmentally.

The magnitude of the earth work involved negatived the idea of the dyke being constructed by manual labour only . The whole operation involved cosideable lead and lift. This would obviously have increased the unit cost of earthwork and the progress too would have been slow. The straight average distance of the borrow areas from the dyke varies from 200 ft. to 900 ft. At places the lead was difficult and circuitous due to non-availability of suitable soil in the vicinity. These circumstances indicated employment of mechanised operation of digging and transporting the particular kind of earth that was suitable for such embankments. The work was therefore, carried out with heavy earth-moving machines. 4 scrapers, 3 roadsters, 3 dozers, and 2 graders were put in commission for the job. The scrapers, Cat. DW 21 used on this job were the largest employed in the whole Project.

The scrapers, while self-loading are pushed from the back by dozers and when they were fully loaded, they moved on their own power and deposited the earth on the dyke as required. Afterwards a grader spread and levelled the earth in uniform layers before it was watered and finally rolled. For quick progress, the haulroads had to be kept in good order by graderlevelling and frequent watering.

The compaction was done departmentally with the help of tractors and sheepsfoot rollers. Arrangement for adequate water supply for compaction was a difficult problem. The nearest source of water was the river Mahanadi which is now under submergence

but was then situated at a distace of four miles from the dyke. The temperature of the workspot during the summer months, which unfortunately constitutes about half the working season, rises to 120° F in the shade. Consequently, the loss due to evaporation is very high. About 300,000 gallons of water was brought every day to the dyke from the river through pipelines by pumping in two stages. The pumps installed at the river intake discharged through the delivery lines into open tanks situated at about 1000 ft from the middle of the dyke from where water was pumped again to the worksite through pipe lines laid along the whole length of the dyke. Due to non-availability of cheap power at the intake, diesel pumps had to be used at the riverside and the second stage pumping was done by both electric and petrol pumps.

The stones available in the locality of the dykes were unsuitable for riprap. They were mostly disintegrated rocks and poor sandstones. Suitable quarries therefore had to be located at some distances from the worksite, where adequate quantity of stones of desired specification were available. At this job granite, dolomite and quartzite stones have been used for the riprap and in the graded filters. Quarrying of rubbles as well as their placement was done by skilled labour specially trained in the art and imported from the South.

Fig. 5— Caterpillar DW 21 in operation at Right Dyke.

Left Dyke

As already mentioned, there are five gaps in the left dyke.

Gap I

Gap I is a high earthen embankment. It is 5,450 ft. long and 88 ft. at the deepest point. The design of this section of the gap is different from that of the other dykes obviously because of its height. The cross-section is shown in figure 6. Whereas in the case of the other dykes where the maximum height is less than 50 ft., only one berm has been provided at R. L. 620, in the case of this dyke where the maximum height is 88 ft. 2 berms, one at R.L. 620 and another at R.L. 590, have been made. In the upstream side also, one 10 ft. berm has been provided at R.L. 580.

The upstream riprap is 4 ft. thick as compared to 2½ft. pitching in the other dykes. Unlike the other

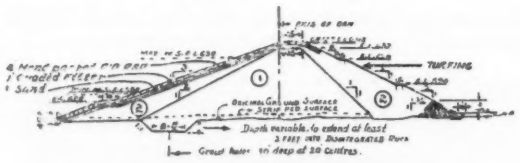


Fig. 6— Cross-section of Left Dyke Gap I.

gaps this embankment is zoned with an impervious core in the centre and semi-pervious deposits on either side. The borrow areas for this work were situated at a distance of more than a mile. The work was done departmentally by means of shovels and heavy earthmoving machines. The total cost of this work is Rs. 1,59,61,374/-. The quantities of the main items of construction are given in table 2.

Fig. 7— A view of the Left Dyke Gap I

Gap II

This is described later.

Gap III

The third gap is a 10,800 ft. long earthen embankment with a maximum height of 30 ft. Due to convenient height and availability of soil just by the side of embankment, this work was done by manual labour, through a contractor. Hard and sound granite stones were also available within convenient distances for the rubble work. The supply of sand and the graded filter was done from the river bed. River shingle of varying sizes served as good graded filters. The quantities of work involved are given in table 3. The total cost of this work is Rs. 19,90,000/-.

Gap IV

The fourth gap of the left dyke is a 10,200 ft. long earthen embankment with an average height of 30 ft. and maximum height being 40.18 ft. This work was carried out by machines on contract. The distance of the source of water supply in this case was only about 2 miles. There was no difficulty regarding the availability of stones, also. The work has cost about Rs. 42,46,000/-. The quantities of work involved are given in table 4. The main canal of the left bank called the Sason Canal takes off from this dyke. The head regulator which is situated in this dyke is described later.

Gap V

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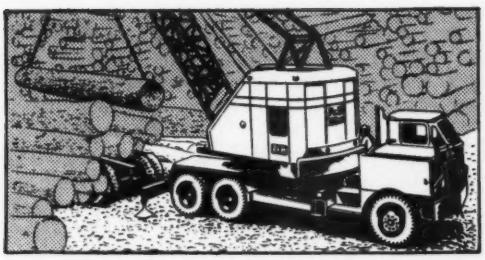

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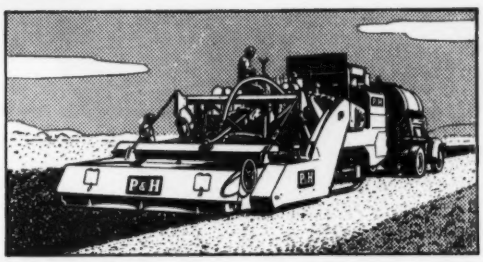

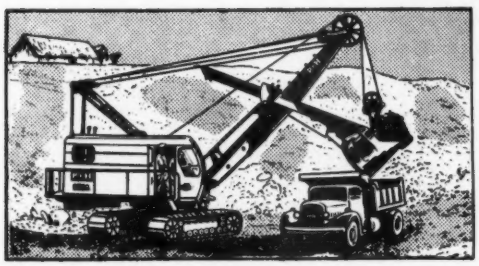

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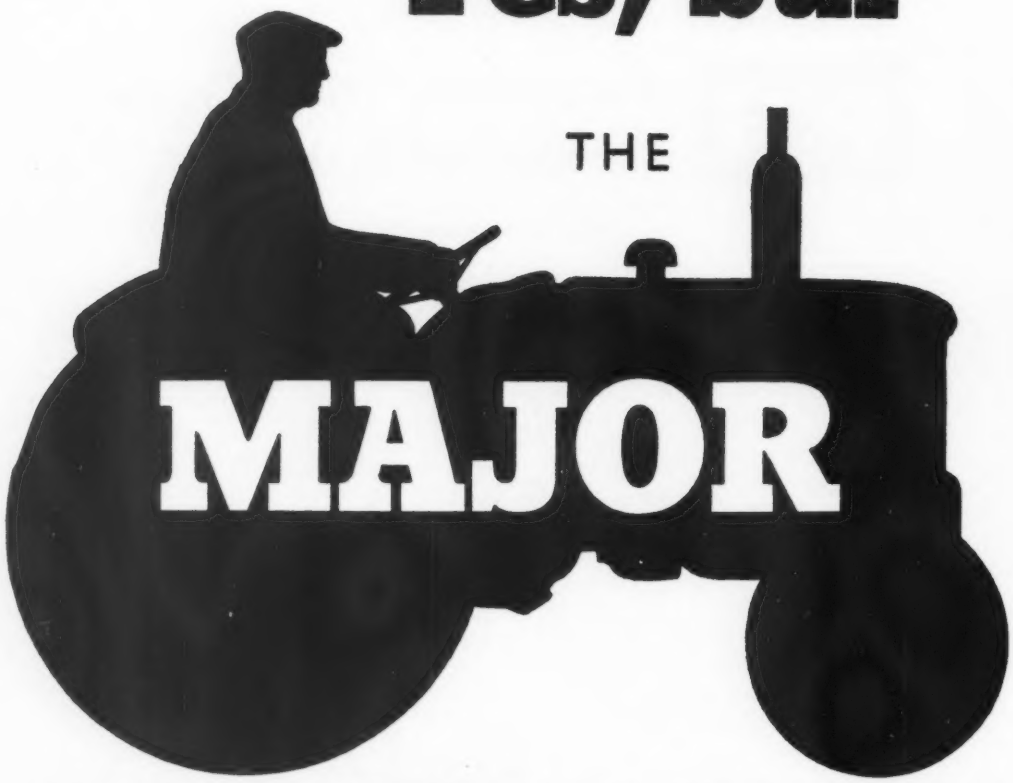

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Fig. 8— Work in progress in Left Dyke Gap I

Fig. 9— A view of the Left Dyke Gap III

2,080 ft. in length. The maximum height in this case is 45.30 ft. This work was done by contract. In the construction of this dyke, the contractor employed manual labour, mules and also diesel locos with tip wagons. Here it was a competition between the three means of transporting earth and the mules proved to be the most economical. This work has cost Rs. 8,30,608/-. The details of the quantities are given in table 5

Fig. 10— Earthwork being done by mules in Left Dyke.

Fig. 11— Earthwork being done by tip wagons in Left Dyke.

In all these dykes, the original design provided zoning of the earthen embankment. The borrow areas for earth suitable for zoning were not available within easy reaches. The design had to be modified therefore to suit the nature of soil obtained from the borrow pits. Zoning was abandoned and a composite section adopted for all gaps other than the first.

Bargarh Canal Head Regulator

As described earlier, the main canal of the Hirakud Canal system takes off from RD 29,000 of the right dyke. This is called the Bargarh Canal. It commands 3,80,000 acres of culturable land on the right side of Mahanadi river. It starts with a bed width of 150 ft. and a F.S.D. of 8.5 ft. The head regulator is designed for a total discharge of 5,750 cusecs with a design head of 2.25 ft. The front of the regulator upto a length of 40.3 ft. consists of a R.C.C. breast wall and the gate operation arrangements. The masonry piers separating the flows from the various sluices start from here. There are 8 vents of 7′-6″×9′6″ at the entrance which end beyond the headwall into 4 nos. 20 ft. wide masonry barrels with arch coverings. The original design was made for 4 sluice openings each 17′-9″ wide so as to use some surplus gates. But later these gates were not available and so the design had to be altered. The latest design has the aforesaid 8 vents each with its own control. The main barrels are separated by 5 ft. thick masonry piers. The covering arch is made of 3 ft. thick mass concrete (1:2:4) and has a rise of 5 ft. The barrels extend along 196.6 ft. beyond the front structure and finally discharge into the main canal after passing over a 3 ft. high baffle and a 50 ft. long concerete floor which extends into another 70 ft. loose apron. The arch over the barrel is designed for the superimposed earth load. The abutments have been designed as simple retaining walls. The computed maximum stresses in the abutments and the piers are 6.25 tons per sq. ft. and 10.85 tons per sq. ft respectively which are supposed to be well within the strength of the masonry provided. The maximum bearing pressure at the foundation under the piers works at 4.27 tons per sq. ft. A bearing test for the foundation soil was carried out which indicated a safe load of 10 tons per sq. ft. Originally it was proposed to make the approach to the gate operation platform by a truss bridge 10 ft. wide. Lately it has been decided to construct a suitably protected earthen embankment in place of the bridge which will considerably reduce the cost of the approach. This is being kept at the same height at that of the dyke and is provided with a 16 ft. road on the top. Masonry cut-offs have been provided on either side of the regulator at the intersection of the cut-off trench of the main dyke.

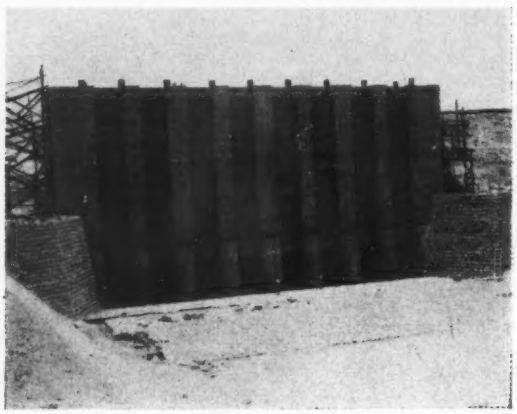

Fig. 12— A view of Bargarh Canal head regulator upstream.

A general outline of the head-regulator is shown in in figure 11. The estimated cost for this work is about Rs. 16,60,000/-. The gates which are estimated to cost about Rs. 3,00,000/- are being manufactured by the Thungabhadra Workshop. The whole regulator structure is built partly in reinforced concrete and partly in stone-masonry on mass concrete foundation. Good building stones were available within four miles of the locality. It was considered desirable to make use of the locally available stones in building a masonry structure which besides satisfying all the necessary

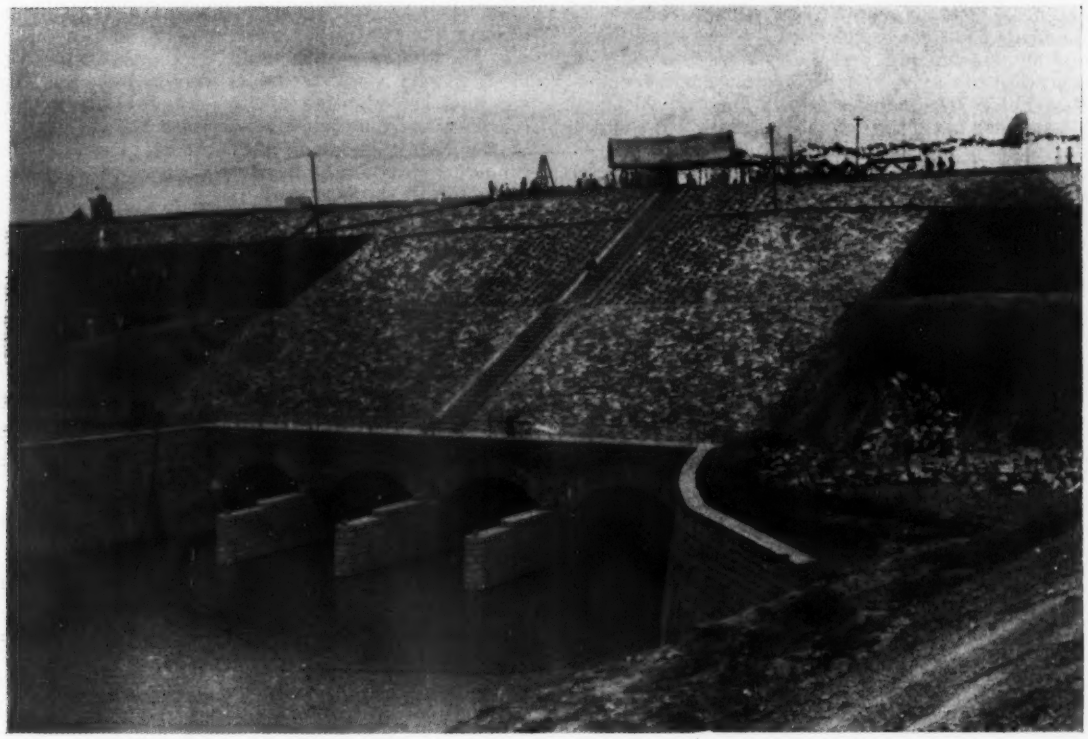

Fig. 13— Bargarh Canal head regulator—downstream view.

requirements of the case promised additional advantages. Such a structure was durable, resistent to erosion, watertight and has strength to withstand the compressive stress imposed with a fair margin of safety. It gave additional benefit of cheapness, and afforded scope for ample employment of manual labour. Incidently, it required lesser quantity of cement than cement concrete and was easier to work.

The quantities of the main items of construction are given in table 6.

Sason Canal Head Regulator

This Head Regulator is situated at R. D. 38,000 of the IV gap of left dyke. It has a discharging capacity of 630 cusecs. The canal will command a culturable area of 62,177 acres.

The structure consists of a masonry head-wall and masonry barrel with a concrete arch at top. The head-wall consists of rubble masonry and has a top width of 10 ft. There are two openings provided with gates and separated by a concrete pier. The two vents combine together into a single barrel. The barrel is 14 ft. wide and 5 ft. high upto springing. The arch rises 3.5 ft. above the springing. The thickness of the arch is 2 ft. over a length of 40 ft. in the middle which is subject to the maximum superposed loads. The flooring is paved with dressed stones.

The gates for the sluices are operated by the openings provided in the headwall. A bellmouth transition has been provided at the entry.

The foundation is laid in 1: 4: 8 mass cement concerete, 4 ft. thick over hard shale. A bearing test carried on the foundation indicated a safe capacity of 9.5 tons per sq. ft. as against which the maximum bearing pressure on the foundation works at 4 tons per sq. ft. only. The barrel extends along 216 ft. beyond the front structure and then discharges into the 55 ft. wide canal after passing over a 1½ ft. high R.C. baffle wall and 40 ft. long apron consisting partly of masonry and partly of stone pitching. The wing walls on the downstream side are made in coursed rubble masonry They are suitably curved and battered to provide the transition expansion from the barrel to the beginning of the canal. The general outline of the head-regulator is shown in figure 12.

Gap II and Sambalpur Canal Head Sluice

The second gap which is only 432 ft. in length has been filled up by a masonry structure. The height at the lowest point is about 70 ft. Two canals take off from this dyke with a combined discharge of 120 cusecs and will command a culturable area of 11,800 acres. The narrowness of this gap together with the height involved suggested the building of a masonry structure. The structure is a gravity type dam and is constructed of rubble masonry in cement motar.

The foundation rock at this site presented some difficulty as it contained quartz and mica schists with longitudinal fissures which were not amenable to blasting. The charge from the explosion got dissipated through the innumerable fissures in the flaky rocks producing little or no result. Even grout oozed out if pushed under high pressure. The foundation, therefore, had to be excavated to the desired

depth by wading and barring along. Though the foundation was cut to firm rock, yet the small cracks and fissures remained and there seemed no end to it; otherwise the exposed rock was masonry structure. Fortunately the fissures had a longitudinal trend, all parallel to the axis of the dam with a favourable dip towards the upstream side. Whereever the excavation revealed zones of weathered rock of appreciable width or small longitudinal cracks filled with soft stuff they were excavated to a depth of at least twice the width of the weak zone and plugged with mass concrete. As a further precaution, 1,230 ft. of grouting was done in this foundation.

Fig. 14 — Left Dyke gap II before work was taken up.

The superstructure masonry consists of face stones hammer dressed with bushes not projecting beyond 3/4 inch and the sides, bed and top one line chisel dressed for 4 inches from face and built with courses normal to the batter. The hearting is of random rubble. For random rubble masonry, stones received from the quarries were used without any dressing except knocking off weak corners, and were set in the work on their flat beds, breaking joints as far as posible. For the face work only selected stones were used. In each course the stones were laid as headers and stretchers alternately with joints breaking in the coarses above and below by at least $\frac{1}{2}$ the height of the coarse in which they occure. The random rubble masonry in the hearting was carried simultaneously with the face work. To ensure water-tightness, the face joints are being pointed with cement mortar. The general features of the construction are given in figure 15.

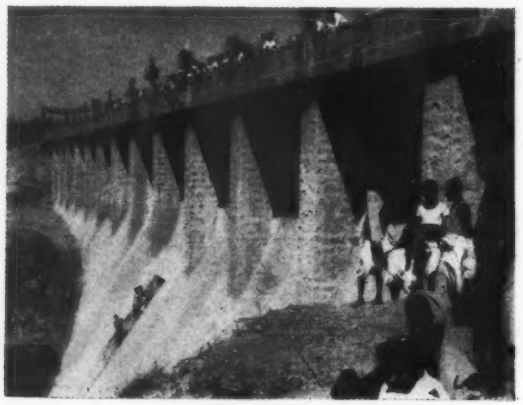

Fig. 15— A view of Left Dyke Gap II

This structure has cost Rs. 5,56,700/- Table 8 shows the quantities of different items of the work.

Acknowledgement

Sri R. Rangachari very kindly collected the necessary materials for this article. I deeply appreciate that help.

(*Continued from page* 73)

Field Testing and Quality Control

cyds of concrete placed. The specimens were tested at the ages of 7 days, 28 days, 90 days, 6 months and 1 year. A regular testing schedule was followed according to which out of every 36 specimens moulded, 9 were tested at 7 days, 18 at 28 days and 3 each at 90 days, 6 months and 1 year.

The test specimens were 6″×12″ cylinders in the case of concrete and 2″×4″ cylinders in the case of mortar.

In the case of Earth Dam, the scale of sampling for testing adequacy of compaction was of the order of one for every 10,000 cft. of fill.

Acknowledgement

The contribution of the Hirakud Research Station and its field laboratories to the construction of the Hirakud Dam and its allied works might not appear spectacular; none the less it was valuable. The laboratory derived its strength from the continued support of the Chief Engineer Shri M. S. Thirumale Iyengar who upheld the reasonable objections and suggestions emanating from the laboratory, even though such objections and suggestions often had repercussions on the construction schedule. The team-work of the personnel of the laboratory contributed a great deal to the laboratory's usefulness to the Project.

PERSONNEL CHART OF HIRAKUD RESEARCH STATION

Deputy Director

Soil Section		*Concrete Section*		*Silt Section*		*Chemical Section*	
Research Officer	1	Research Officer	1				
Assistant Research Officer	1	Assistant Research Officer	1				
Research Assistants	7	Research Assistants	6	Research Assistants	2	Research Assistants	2
Analysts	5	Analysts	4	Analysts	2		
Inspectors	10	Inspectors	6				
Assistant Inspectors	14	Assistant Inspectors	6				
Laboratory Assistants	2			Laboratory Assistant	1	Laboratory Assistants	1
Laboratory Attendants		Laboratory Attendants		Laboratory Attendants		Laboratory Attendants	

The chart represents the strength of the Station during the peak period of work in the field.

TABLE I

Right Dyke

1. Earthwork in embankment (compacted)	..	9,73,60,000 Cft.
2. Compacting of earthwork	..	11,68,32,000 Cft.
3. Earthwork in excavation	..	1,01,11,000 Cft.
4. Rubble packing	..	1,08,74,000 Cft.
5. Graded filter	..	20,50,000 Cft.
6. Sand spreading	..	18,33,000 Cft.
7. Parapet	..	70,000 Cft.

TABLE II

Left Dyke-Gap I

1. Earthwork in embankment	..	4,72,30,000 Cft.
2. Graded filter	..	27,62,000 Cft.
3. Dumping and packing	..	50,68,000 Cft.

TABLE III

Left Dyke-Gap III

1. Earthwork in excavation	..	1,76,03,000 Cft.
2. Compacting of earthwork	..	2,14,91,000 Cft.
3. Rubble packing	..	17,15,000 Cft.
4. Spreading graded filter	..	5,23,000 Cft.

TABLE IV

Left Dye-Gap IV

1. Earthwork in excavation	..	2,79,48,000 Cft.
2. Compaction of earthwork	..	3,35,38,000 Cft.
3. Earthwork in stripping	..	22,15,000 Cft.
4. Rubble packing	..	26,00,000 Cft.
5. Spreading graded filter	..	7,41,000 Cft.
6. Sand spreading	..	2,06,000 Cft.

TABLE V

Left Dyke-Gap V

1. Earthwork in excavation	..	74,49,000 Cft.
2. Compaction of earthwork	..	89,35,000 Cft.
3. Earthwork in stripping	..	8,85,000 Cft.
4. Rubble packing	..	5,37,000 Cft.
5. Spreading graded filter	..	1,45,000 Cft.
6. Sand spreading	..	59,000 Cft.

TABLE VI

Bargarh Canal Head Regulator

1. Cement Concrete 1 : 4 : 8 in foundation	..	1,42,000 Cft.
2. R. C. Masonry in superstructure	..	1,73,000 Cft.
3. Cement Concrete 1 : 2 : 4 in foundation	..	25,000 Cft.
4. Earthwork in foundation	..	22,20,000 Cft.
5. R. C. C. work	..	46,000 Cft.
6. C. C. 1 : 3 : 6 in arching	..	60,000 Cft.
7. Coursed rubble work	..	71,000 Cft.
8. C. C. 1 : 5: 10 in hunch filling	..	56,000 Cft.
9. Mild steel reinforcement (lbs)	..	2,40,000 Cft.

TABLE VII

Head Regulator at Left Dyke IV (Sason canal)

1. Earthwork in excavation and filling	..	3,45,000 Cft.
2. C. R. M. including archwork and chisel dressing	..	57,000 Cft.
3. R. C. C. work	..	8,000 Cft.
4. Cement Concrete	..	62,000 Cft.
5. R. R. Masonry	..	24,000 Cft.

TABLE VIII

1. Cement concrete	..	17,000 Cft.
2. R. R. Masonry in Cement Mortar	..	2,30,000 Cft.
3. R. C. C. work	..	11,000 Cft.
4. C. R. Masonry	..	47 000 Cft.

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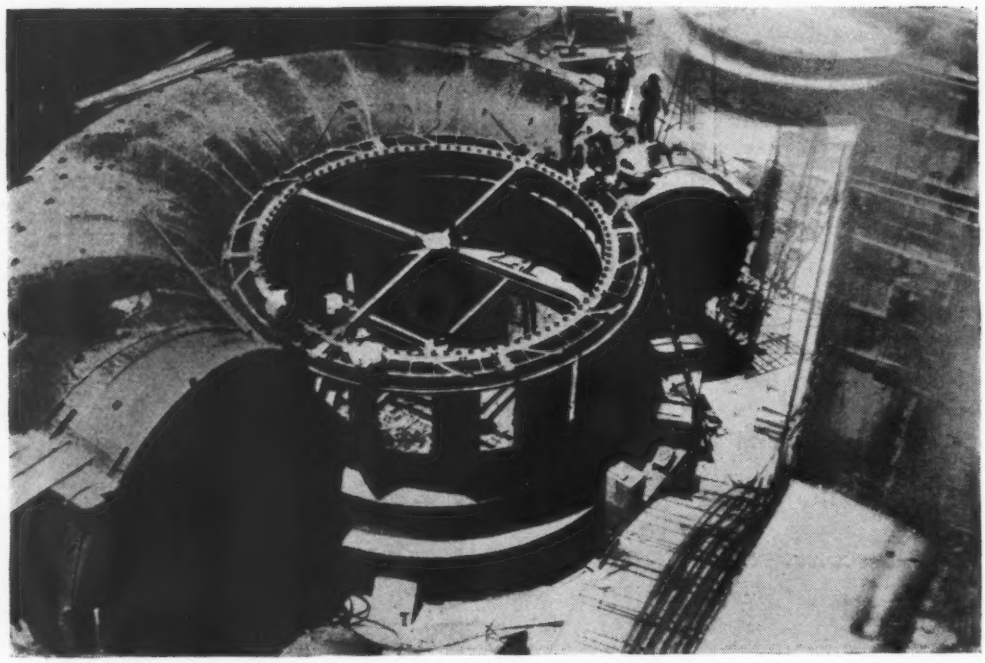

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EEC-34

The Hirakud Power System

By

N. DHARMARAJAN, B.E., M.A.I.E.E., M.I.E. (Ind)

Superintending Engineer in Electrical charge of the Power System, Hirakud Dam Project

AUTHOR

The Hirakud Power System will unfold the rich mineral potentialities of Orissa State which have remained undeveloped for centuries. As soon as power generation was taken in hand, side by side with long term economic development planning of the country, it was found that Orissa can consume much more power than one could dare think at the initial stages. Orissa is now worrying about the shortage of power in the immediate future, even before Hirakud Power could be generated in full. So tremendous, is the pace of development vitualised. In the contribution the Author surveys the Generation and utilisation of Hirakud Power and deals with the technical features of the plant.

The State of Orissa is singularly fortunate in being blessed with enormous mineral resources especially iron ore, plenty of potential water power and not an insignificant quantity of coal that can be used for steam raising purposes. Such a combination of potential wealth, if developed by great construction activity, will add enormously to the production of much needed goods and enable a long stride to be taken towards more comfortable living of the people.

So far as potential water power is concerned, northern Orissa has three huge rivers (the Mahanadi, the Brahmani and the Baitarani) flowing through the State carrying enormous quantity of water during the monsoon moths viz. June—October.

The average annual flow of Mahanadi near Hirakud is about 40 to 50 million acre feet. The average annual flow of Barahmani and Baitarani are 22 and 5.9 million acre feet. The Hirakud Dam as at present constructed impounds only 6.6 million acre feet and the balance of the water is still available for harnessing lower down. With the storage now available in the Hirakud reservoir, the ultimate scheme for power generation is to install 5 sets of 37,500 K.W. and 2 sets of 24,000 K.W. at the main Dam and by leading the tail waters by means of a channel 12 miles downstream and utilising the difference in level of 78 ft. between the end of the channel and the river to install further generating units aggregating 72,000 K.W.

The river Mahanadi, 100 miles below the location of the Second Power House, flows through a gorge which is ideally situated for location of another dam and utilising the perennial flow of 12,000 cusecs released from the Hirakud Dam. Power to the extent of 2,00,000 K.W. can be generated here.

In the River Brahmani also there are two sites where the river can be dammed and power to the extent of 40,000 K.W. can be generated

The river Baitarani, the northernmost of the three rivers, in its later reaches flows through the Mayurbhanj plateau about 1,000′ above sea-level and before the coastal plains falls through a depth of 800 ft. in the course of 8 miles. This is an ideal location for generation of power and it is estimated that power to the extent of about 250,000 K.W. can be developed here. These three rivers alone when fully harnessed will produce nearly 800,000 K.W. of power.

Southern Orissa's water power potential is also sufficiently great and it may be reckoned as about 200,000 K.W.

As already mentioned, the Hirakud Power System, when completed in all respects as per present proposals, will consist of two hydro-electric Power Houses—one at the mighty Hirakud Dam across the Mahanadi river (of which full accounts appear elsewhere in this issue) and the second about 12 miles downstream. The power potential of the first Power House is derived from the huge storage of 6.6 million acre feet of water behind the Dam (of which 4.72 is the live storage) and that of the second Power House is derived from the tail waters of the first Power House being led through a power channel (with a carrying capacity of 12,000 cusecs) and a head of about 78 feet available between the end of this 12 mile channel and the Mahanadi River. A map of the area showing the positions of the main Dam, the Power Channel and the position of the two Power Houses is given is Fig. 1.

Salient Hydraulic Features

The salient hydraulic features of the reservoir so far as they relate to power production are given below.

Top of Dam	..	R. L. 640
Full supply level	..	R. L. 630
Minimum water level	..	R. L. 590
Normal Tail water level	..	R. L. 516
Minimum Tailwater level	..	R. L. 510
Maximum Tailwater level	..	R. L. 525
Storage capacity of the Reservoir		6.6 million acre ft.
Live Storage		4.72 million acre ft.

The operation of the reservior

The operation of the reservior will depend on the season. During the monsoon months of June—September, the level in the reservoir will be kept at R.L. 590 so as to make available the balance capacity of the reservoir (4.72 million acre ft.) for flood absorption purposes. During this period, the generating units at the main dam will be working at the minimum head of 73 ft. The average daily discharge in tail race which is kept separate from the river by a training wall will be 12,000 cusecs under these circumstances.

The reservoir will be filled up to R.L. 630 by 1st of October every year and from then on the water in

the reservoir after meeting the needs of Sambalpur irrigation (2.448 million acre ft) and evaporation losses (59 million acre ft.) aggregating to 3·038. million acre ft. be so utilised that the maximum average daily power will be obtained by the integrated operation of Power House No. 1 and Power House No. II. For this purpose the quantity of water let down through the turbines of the first Power House will vary from about 9000 cusecs in October to 12,000 cusecs in June due to the variation in the head in the main dam.

Such an operation will yield 128,000 K.W. of power at 100% load factor. At 70%, which is expected to be the average load factor of the system, the firm water-potential of the system will be 180,000 K.W.

The Power House at the Main Dam

This power house is situated at the toe of the masonry Dam at the extreme right. The Power House will ultimately consist of 7 generating units, 5 of which will have a capacity of 37,500 kilowatt and 2 of 24,000 kilowatts. The machines already under installation comprise 2 units of 37.500 K.W. and 2 units 24,000 K.W. Installation of one more unit of 37,500 K.W. has been sanctioned and work will commence shortly. It is possible that the sixth unit may also be installed within the Second Five-Year Plan.

Penstocks and Headgates

Seven penstocks of 25′ dia. for the seven machines ultimately projected (the biggest of this type so far installed in India) have been provided and the admission of water into these penstocks is to be controlled by headgates hydraulically operated by oil pressure servomotors and of size 31′×18′. The smooth transition from this rectangular opening to the circular penstock liner is made by various elliptical sections moulded in heavily reinforced concrete. The formwork of wood and cover plates used for this was of a huge size and had a weight of 20 tons.

At present only 4 head gates with servomotors for their operation have been installed and the fifth and sixth penstock openings have been temporarilly closed by stop logs of steel construction. The seventh penstock is temporarily closed by a concerete curtain wall suitably stiffened to withstand the pressure of water on the upstream side.

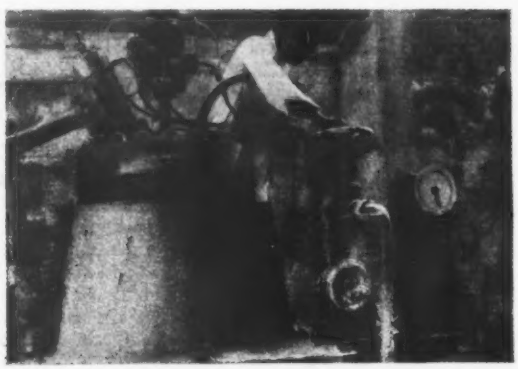


Fig. 3. Servomotor—simple looking but powerful enough to lift 60-ton penstock gate.

Besides these, provision has been made for emergency closing of these openings at the face of the Dam by bulk head gates consisting of 4 leaves for closing an opening of 41.39′×23.448′.

The embedded parts of the openings were installed in May and June 1955, but the gates could not be installed as the Dam was only half finished. These openings had to be closed in June, 1955 with some of these gate parts in a temporarily assembled condition to prevent water from flooding the Power House during monsoon period. Further work on these gates could not be started till end of February, 1956 as the work on the dam could only be resumed in November after subsidence of the floods and the dam had to be built to sufficient height to enable uninterrupted work on the gates.

As the reservoir was scheduled to be filled durng the coming monsoon period, it was necessary to close the openings before end of May. In addition to the short time available for the installation of the gates another serious handicap was that there was no gantry crane available for the erection of the gates. The gates had to be assembled, welded, and the seals fixed inside the gate slot by suspending the assembled gate in the slot from the top and lowering the heavy gates weighing about 60 tons by means of ordinary winches from the top. Only three of these gates could be lowered before the first freshets came in the river and this created an added complication, viz. closing the fourth opening at the face of the dam with bulkhead gates and working inside the gate slot. In spite of these serious handicaps, all the four gates were completely installed by end of September. This entire work of installation of gates were completed by Indian engineers with local labour except for the assistance of a factory representative to check up alignments etc.

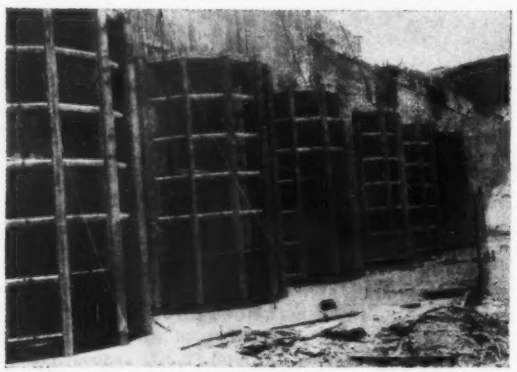
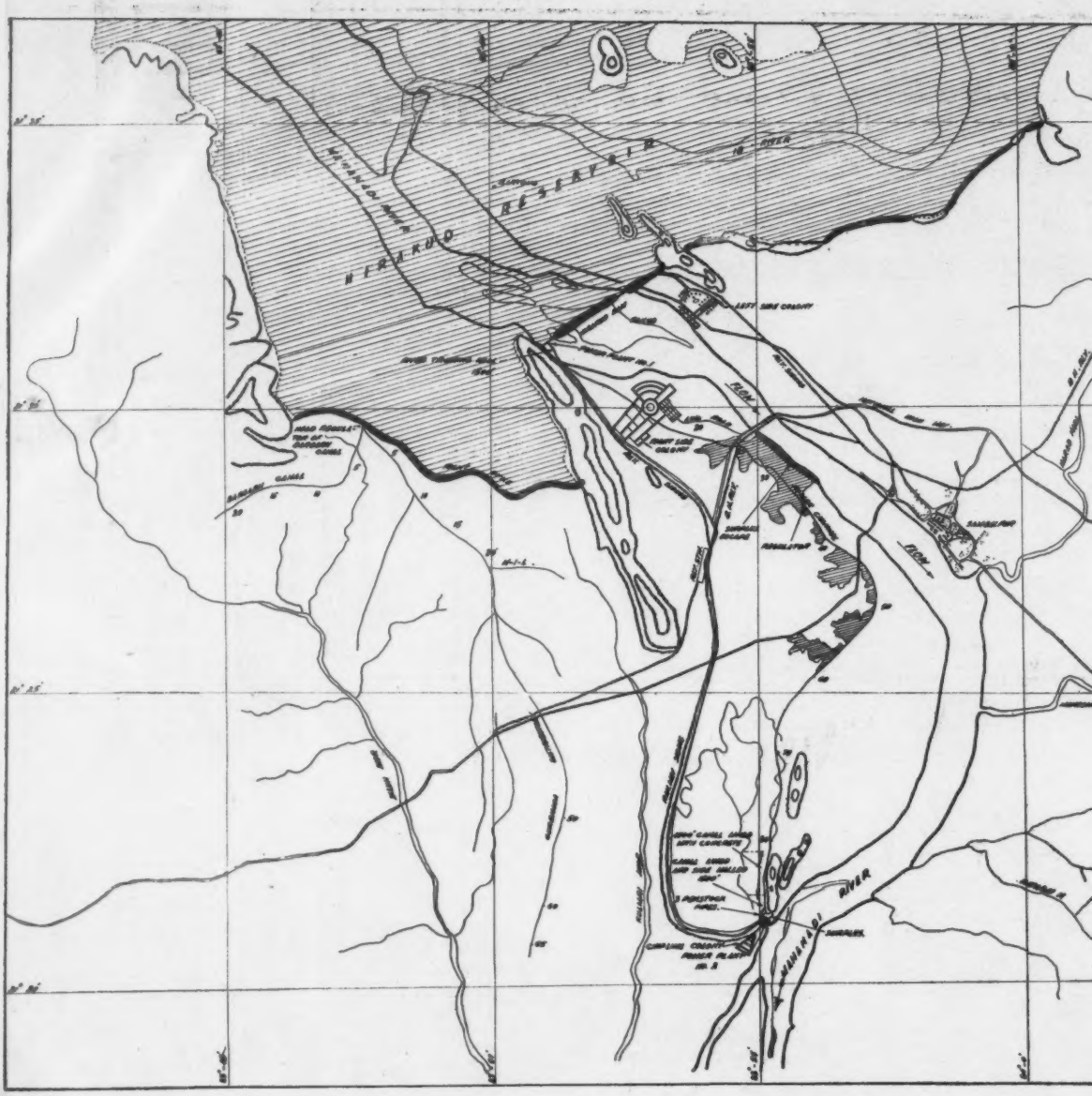


Fig. 4. Trash rack arrangement for Penstock entry. 600 tons of steel have been used in gratings.

The penstock openings are protected against entry of logs and other debris by huge reinforced concrete semicircular trash rack openings fitted with gratings. Each concrete structure has a radius of 25′3″ and a height of 80 ft. Each structure is fitted with 42 massive gratings 11′′5″×11′ 99″ each weighing about 2 tons. Thus the total tonnage of the gratings alone comes to about 600 tons. All the trash rack gratings were manufactured in the Hirakud Workshops.

Generating units

As already mentioned, the present installation


HIRAKUD RESERVOIR
MAHANADI RIVER
RIVER
RIVER
RIVER

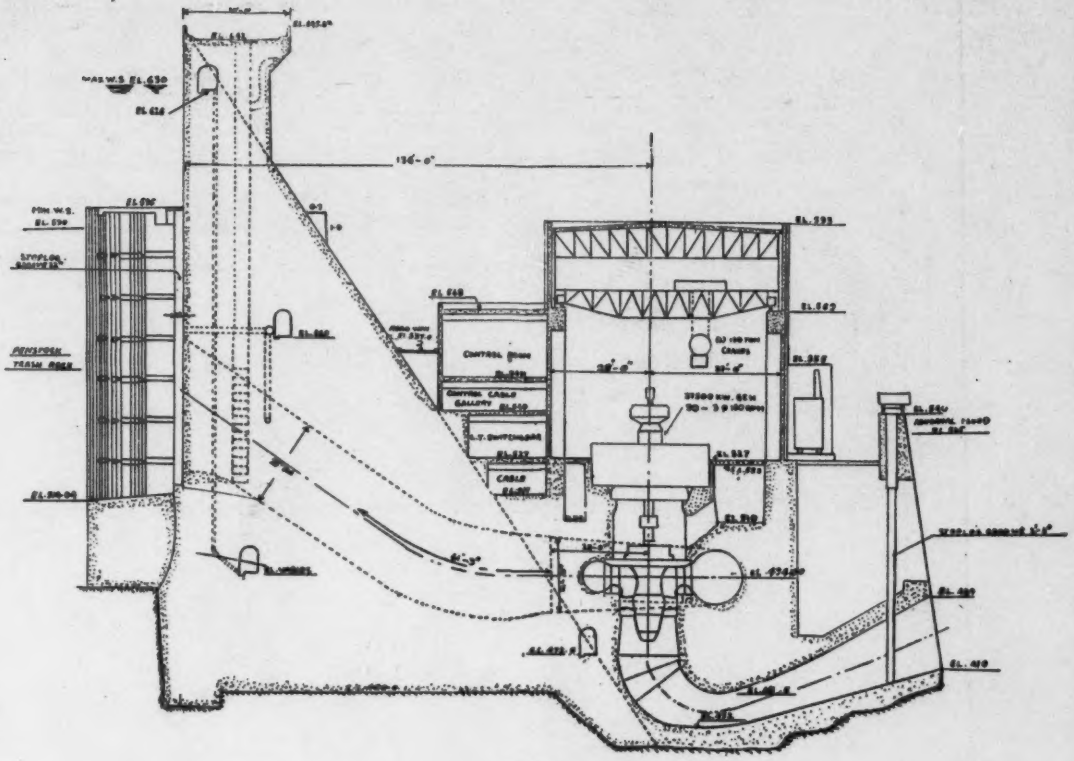


Fig. 2

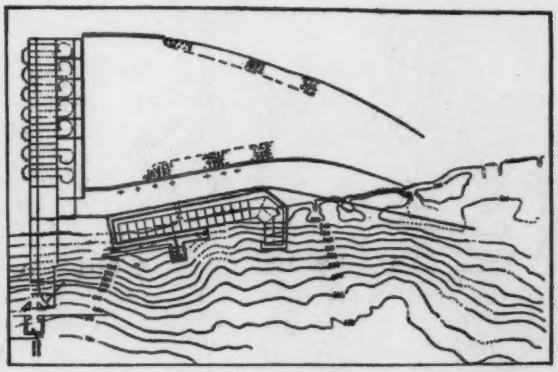
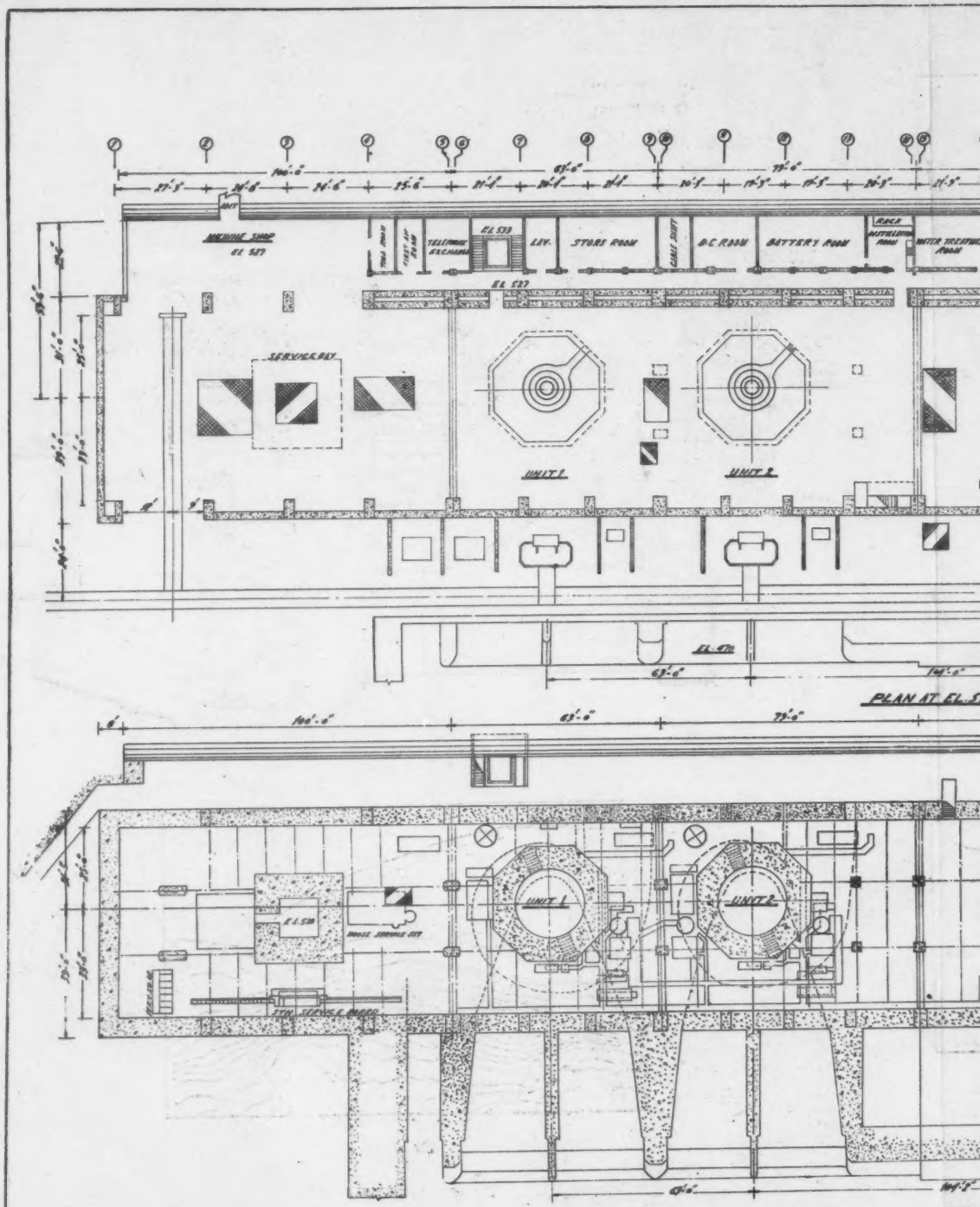


Fig. 5


STORE ROOM
D.C. ROOM
BATTERY ROOM
SERVICE BAY
UNIT 1
UNIT 2
EL. 533
EL. 527
EL. 512
PLAN AT EL.
100'-0"
63'-0"
79'-0"
UNIT 1
UNIT 2
EL. 518
PLAN

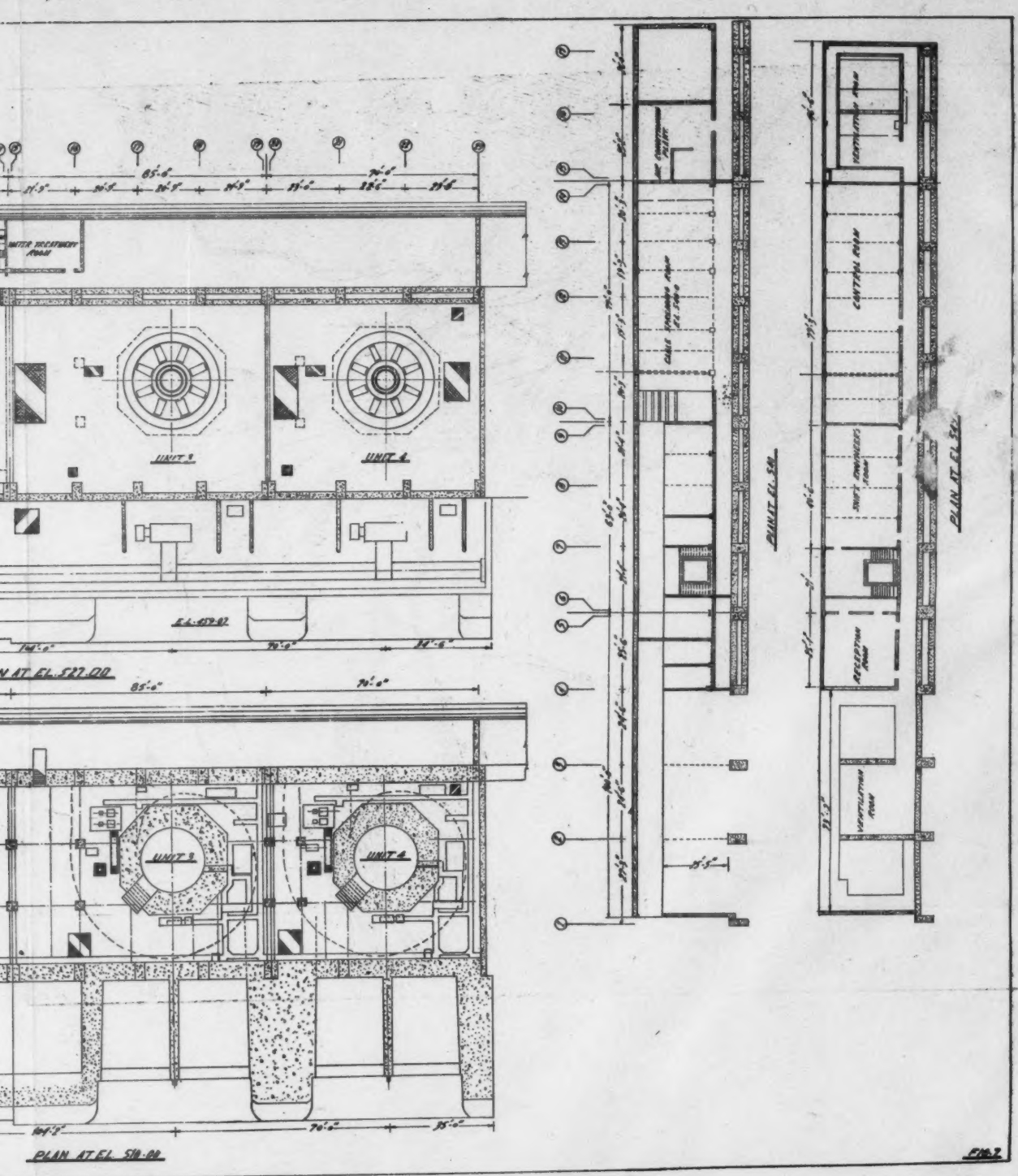
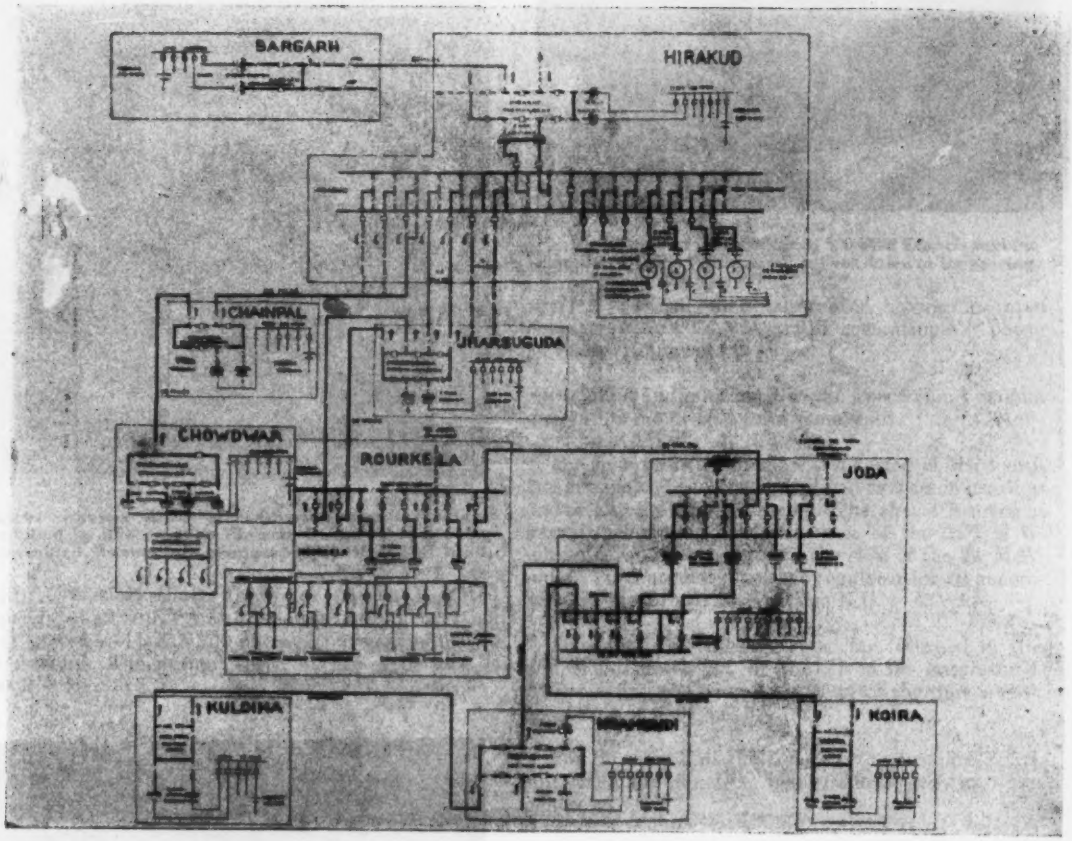
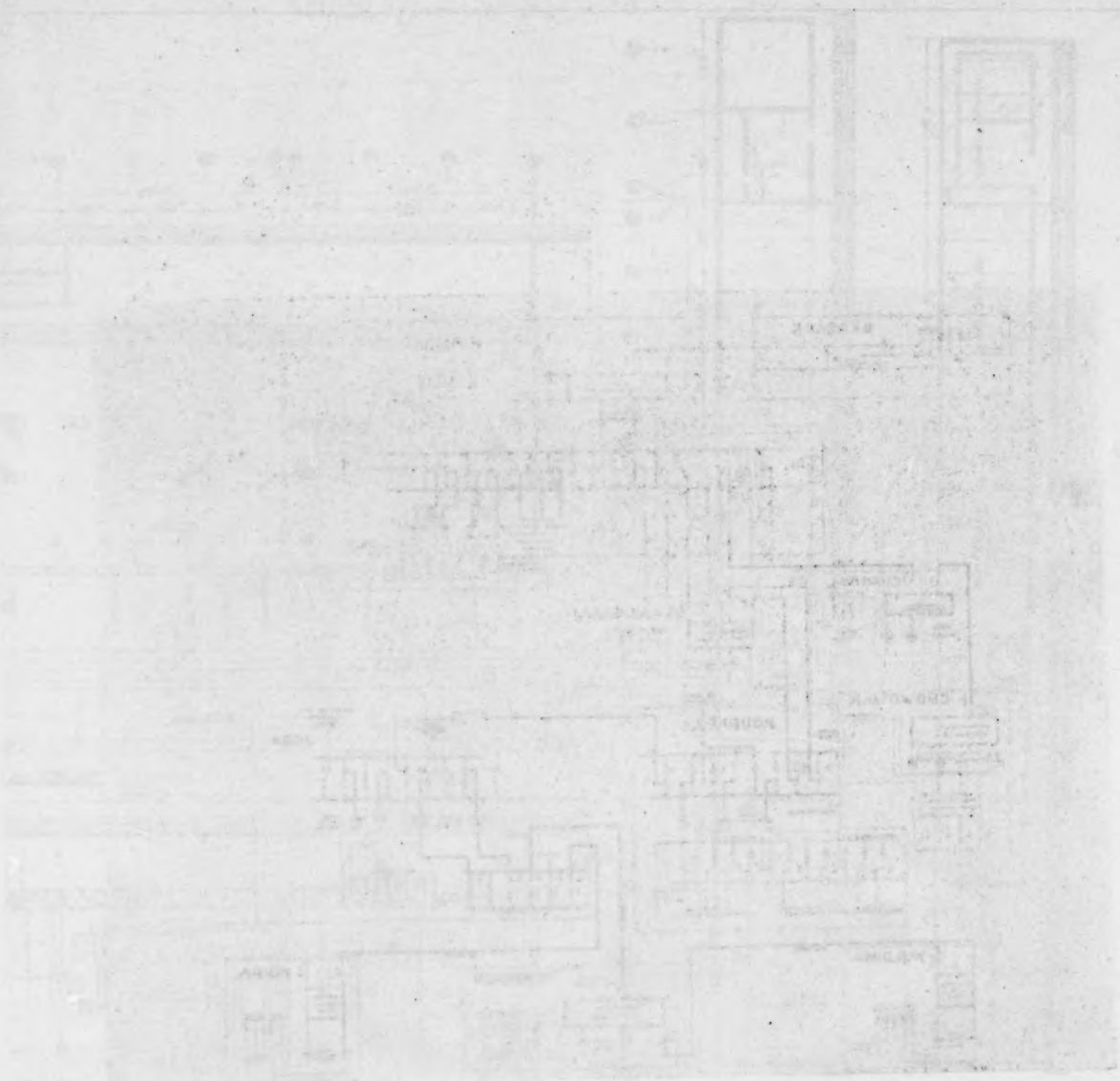

WATER TREATMENT ROOM
UNIT 3
UNIT 4
EL. 497.92
PLAN AT EL. 522.00
UNIT 3
UNIT 4
PLAN AT EL. 510.00
CABLE TUNNEL FLOOR EL. 500.0
PLAN AT EL. 500.
CONTROL ROOM
SHIFT ENGINEERS ROOM
RECEPTION ROOM
VENTILATION ROOM

FIG. 2


SARGARH
HIRAKUD
CHAINPAL
JHARSUGUDA
CHOWDWAR
ROURKELA
JODA
KULDIHA
KOIRA



consists of 2 generating units of 37,500 K.W. and 2 units of 24,000 K.W.

The 37,500 K.W. are supplied by M/s. The English Electric Co. Ltd. and each unit comprises:

(1) One adjustable blade vertical shaft feathering propellor type of turbine having an output of 52,000 H.P. at 87′ head and 41,500 H.P. at 73 ft. head and normal speed of 150 R.P.M.

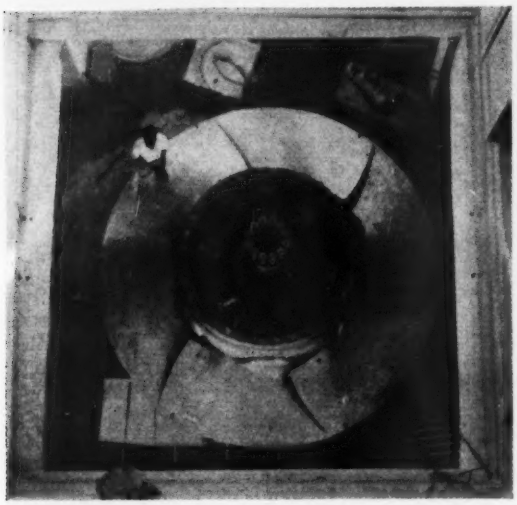


Fig. 6— Runner blades of Feathering propeller turbine supplied by M/s. English Electric Company Ltd. being assembled. Runner will produce 52000 BHP at 87 ft. head.

(2) A vertical shaft alternator having a rated capacity of 42,00 KVA at 0.9 power factor generating A.C. power at 11 K.V. 50 cycles 3 phase coupled to the turbine. The normal speed of the generator is 150 R.P.M.

Fig. 8— Stator coils of 37,500 KW alternator supplied by English Electric Co. The coils that send out juice.

(3) A main and pilot excitor and a permanent magnet generator for the governor pendulum drive mounted on the same shaft.

The 24,000 K.W. sets are supplied by M/s. Protos Engineering Co. and each units comprises the following:

(1) A vertical shaft Francis type of turbine with a rated output of 34,500 B.H.P. at heads 104 to 120 ft. and 23,500 B.H.P. at 80 ft. with a normal speed of 150 R.P.M.

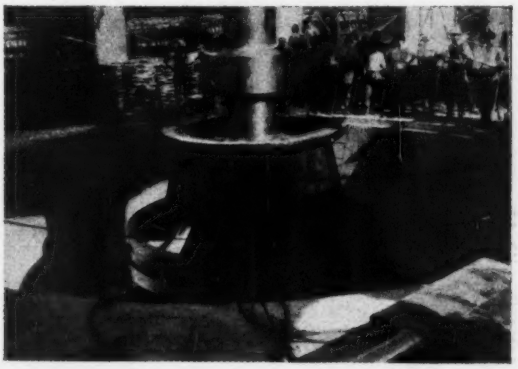


Fig. 9— The giant wheel of the 34,500 BHP Francis turbine supplied by M/s. Voith slowly moves down to its seating.

(2) A vertical shaft alternator having a rated capacity of 27,000 K.V.A. at 9PF generating A.C. power at 11 K.V. 50 cycles 3 phase.

(3) Main and pilot excitors, and permanent magnet generators mounted on the same shaft.

The generators are of the water cooled closed ventilation type and each generator had two guide bearings and a Mitchel thrust bearing. The thrust bearing is located below the rotor in the case of the 37.5 M.W. units and above the rotor in the case of the 24 M.W. units. The automatic voltage regulator for all generators are the Brown Boveri type K.C.

The units are the biggest so far installed in this country. The weight of the 37 M.W. generator is 520 tons and the overall diameter of the unit is 26 ft. at generator floor, i.e. 527.00.

For protection of the generator against fire, provision is made for CO_2 being discharged into the generator.

In addition to the main units, a House Service set with a rated capacity of 600 K.V.A. is installed.

Overhead Cranes

The Power House is provided with 2 overhead travelling cranes each of 150 ton capacity and with a lifting beam connecting the two cranes they are designed to lift a composite load of 300 tons. The cranes were erected and completed by September, 1955. These are the biggest units so far installed in this country.

Main Transformers

Power will be stepped up from the generation of voltage of 11,000 to 1,32,000 by a single transformation and transformers will be directly connected to the generators by bare copper busbars supported on insulators without any intermediate circuitbreaker or switch.

The transformers are all of B.T.H. make and are of the forced oil water cooled type (Type OFW) connect-

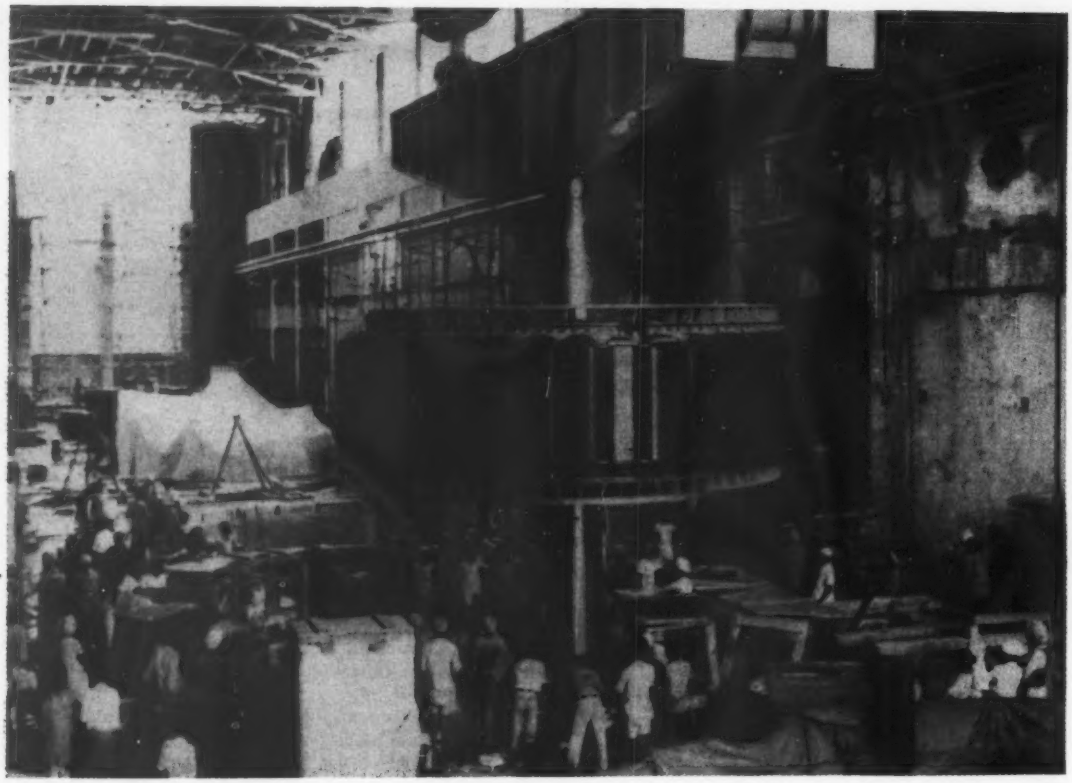


Fig. 10. The 211-ton Rotor of 24,000 KW alternator getting ready to be placed in position.

ed Delta/Star. with netural point of 132 K.V. is solidly earthed. These transformers are located on the deck of of the draft tube.

The 132 K.V. mains from the transformer to the switchyard structure will consist of tubular copper conductor and will be stretched across the tail race channel through towers located at the switchyard.

Out-door Switch Gear

The 132 K.V. switchgear comprises an elevated galvanised steel structure accommodating two sets of busbars and the necessary isolating switches. The structure has 17 bays for accommodating 17 oil circuit breakers. The present installation consists of 14 oil circuit breakers and three more will be installed when the other three units are installed. The circuit breakers are all of the conventional bulk oil type pneumatically operated. From the 132 K.V. busbars the following transmission lines will take off;

(1) One double circuit transmission line 4 miles long to feed an aluminium smelting plant at present under construction at Hirakud.

(2) One double circuit 132 K.V. transmission line 100 miles long to the Rourkela Steel Plant.

(3) One single circuit 132 K.V. transmission line 160 miles long to Chowdwar near Cuttack.

Power is also stepped down from 132 K.V. to 66 K.V. by means of two 12,500 KVA transformers and will be fed into a ring bus through 66 K.V. bulk oil circuit breakers. The 66 K.V. system will feed one single circuit line to Bargarh and will feed two more feeders to outlying districts in the future. The system also feeds two 2,000 K.V.A. transformers 66 KV/11 KV.

The 11 KV side of these transformers feed a 11 K.V. board inside the Power House and feeds 2 transformers of 600 K.V.A. and 2 transformers of 250 K.V.A./11KV, 400 volts to feed all station services and all power and lighting requirements of the Dam.

Control Room

The control gear for the electrical equipment in the Power House and the switchyard will be located in the control room of the main Power House and operation of all the equipment will be remotely controlled from here.

The main protection for the equipment will be differential circulating current protection for the main generator transformer with back up over current protection. For the outgoing 132 K.V. lines, there will be carrier current portection with back up over current. The outgoing 66 KV lines will have distance protection.

Ventilation

The Power House will be provided with forced air ventilation with evaporative cooling. For this purpose 3 blowers each with a capacity 300,000 CFM

Fig. 11. The mighty cranes in Power House successfully fighting the test load of 375 tons.

will be installed. The system is designed to make 12 replacements of air per hour in all the rooms.

The control room will have air-conditioning.

The entire erection of all the equipments is done departmentally with the help of a few supervising engineers loaned by the supplying companies.

One 24,000 K.W. set has been commissioned and the other three machines will be commissioned at intervals of 3 months.

Elsewhere, in this issue will be found a description of the Transmission System.

Prospective loads

With the completion of the 1st and 2nd stages of the Hirakud Dam Project, there wil be an installed capacity 270,000 K.W. and the firm capacity of the system will be about 180,000 K.W.

Prospective loads for this power are as follows:

(1)	Aluminium Factory at Hirakud ..	55,000 K.W.
(2)	Steel Factory at Rourkela ..	60,000 K.W.
(3)	Cement Factory at Rajgangpur ..	5,000 K.W.
(4)	Paper mills at Brajrajnagar ..	4,000 K.W
(5)	Collieries and Refractory Factory near Jharsuguda ..	2,500 K.W.
(6)	Ferro-manganese Factory at Joda ..	16,000 K.W.
(7)	Mining loads at Noamundi, Koira, Joda and Rairangpur..	14,000 K.W.

Fig. 12. Down stream view of the Power House with Power Dam in the background. Power transformers erected on the transformer deck are seen.

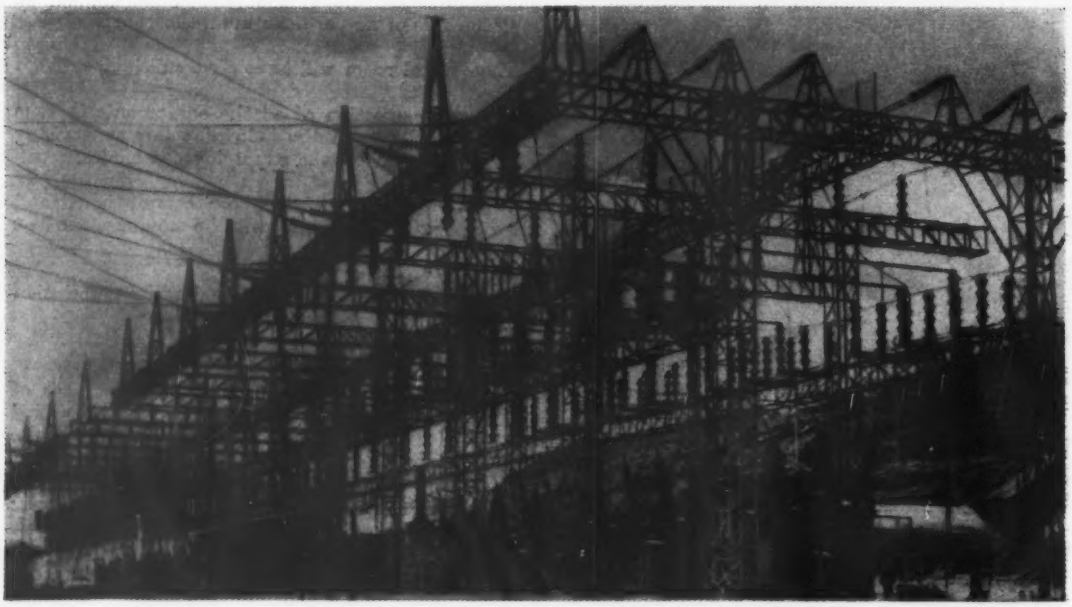


Fig. 13— 132 KV Outdoor Switch-yard—duplicate bus system. A complicated arrangement of structures.

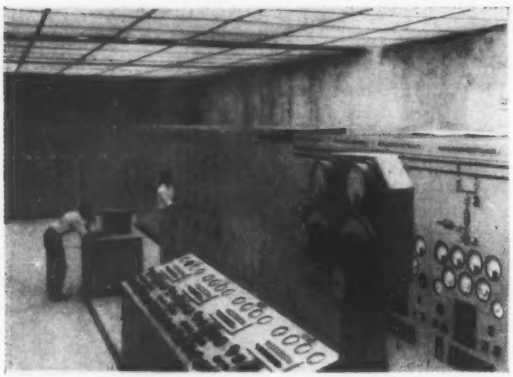


Fig. 14— Silent sentinels guarding the Hirakud Power System night and day.

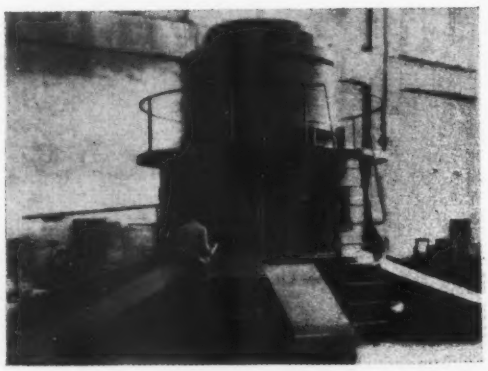
(8)	Load at Cuttack ..	10,000 K.W.
(9)	Bargarh ..	3,000 K.W.
(10)	Station load and other miscellaneous town loads ..	3,000 K.W.
(11)	Line Losses ..	15,000 K.W.
		1,87,500 K.W.

While these loads may be regarded as more or less awaiting supply of power, the projected expansion of the ferro-manganese plant at Joda, the Railway electrification scheme between Kharaswan and Gua and the reasonable standby required for expansion of the electrification which from experience can be predicted to demand power almost at the heels of the 1st stage programme would appear to require immediate planning for further expansion of generating capacity. Non-recognition of this factor will have the effect of retarding progress of industrialisation of the province and making the position of supplies precarious with power cuts etc.

The metamorphosis of a backward province which had less than 10 towns electrified before the advent of the country's freedom, into a highly industrialised state with over 2,70,000 K.W. power catering to industries is to be regarded as a major achievement when the period during which such change will come about is hardly 10 years.

Power exercises a fascination in the minds of all men and there is a jealous longing for electric power from the vast majority of the people of this country who do not enjoy the benefits of this amenity. The advancement of the Western countries during the past 100 years may almost be attributed to the development of this power and the resulting wonderful elimination of human drudgery and slavery had brought about a renewed joy of life. Had this new found joy found expression in extending its bracing

Fig. 15— 24,000 KW set ready for commissioning.



(Continued on page 52)

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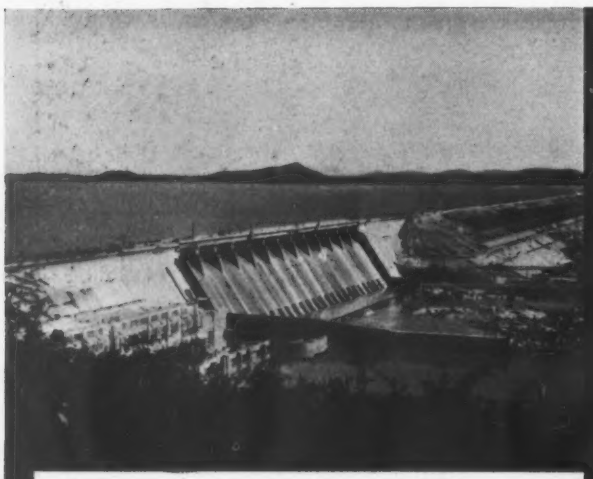

HIRAKUD DAM POWER PROJECT

The inauguration of the Hirakud Dam Power Project by Pandit Nehru, Prime Minister of India, opens a new phase in the economic life of the country. Harnessing the Mahanadi river, the Hirakud Dam Project will bring power to the millions. **A. E. I.** are proud of the part they have played in the supply and erection of electrical equipment.

LIST OF EQUIPMENTS SUPPLIED TO THE HIRAKUD DAM PROJECT

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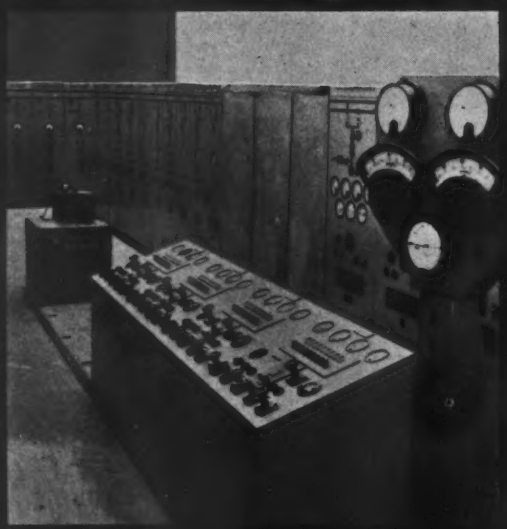
Two 42 MVA, 11/132 kV transformers.
Two 27 MVA, 11/132 kV transformers.
Two 12.5MVA 132/66 kV transformers.
Two 2000 kVA 66/11 kV transformers.
Two 600 kVA 11 kV/420 volts transformers.
Four 200 kVA 11 kV/420 volts transformers.
14 Nos. 132 kV 2500 MVA oil circuit breakers.
6 Nos. 66 kV 500 MVA oil circuit breakers.
34 Nos. 132 kV 400 amps isolating switches.
16 Nos. 66 kV 400 amps isolating switches.
36 Nos. 132 kV single phase lightning arresters.
24 Nos. 66 kV single phase lightning arresters.
One 7 panel 11 kV 75 MVA switchboard.
14 panel 132 kV control & relay boards with 4 control desks and synchronising equipment.
6 panel 66 kV control and relay boards.
4 Nos. neutral earthing cubicles.
4 Nos. surge protection cubicles.
Four 420 volts unit auxiliary switchboards.
One 420 volts station service switchboard.
Two 420 volts switchyard auxiliary switchboards.
One 230 volts 353 amp-hour D. C. battery and battery control board.
Control cables.
Four Nos. oil filtration plants.



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AIC-169

Hirakud Transmission System

By

M. K. GOPALIYENGAR, B.Sc. (Hons)

In charge, Transmission System, Hirakud Dam Project

AUTHOR

One of the most important benefits of the Hirakud Dam Project accruing to the people of Orissa is hydroelectric power on a substantial scale. Orissa is rich in minerals; but these are very much underdeveloped. The power from Hirakud is the key to their development. The Transmission System of this energy, which reaches it to the remote corners of the state, is discussed in this article. It involves 315 miles of 132 KV lines, 105 miles of 66 KV lines in addition a very large network of low tension lines. The author discusses here the technical features of the Towers, Conductors, Insulators, Substation Layout, Transformers, Switchgear, Protections, etc.

If the State of Orissa is to reap the full benefits of the Hirakud Dam Project, the power generated must be fully and speedily utilized; and the problem of transmission and distribution of the electrical energy, therefore, assumes a crucial role in the Project development.

The load potentialities of the Hirakud Project were but dimly understood till 1952, when the Central Water & Power Commission undertook a detailed load survey of the region. This survey highlighted the excellent prospects of siting the Aluminium and Steel industries in this territory. Since then, the setting up of the Aluminium Smelter at Hirakud, the mammoth Steel Plant at Rourkela and the ferromanganese plant at Joda has taken practical shape and the early scepticism about the load prospects in this region has thus proved to be rather unfounded. The transmission system had to take note of these far-reaching developments and had to be suitably re-designed to cater to these sizeable loads. While the Hirakud Organization is charged with the responsibility of designing, constructing and commissioning the H.T. and E.H.T. transmission lines and substations the task of supplying power at the different load centres at 11 or 33 kV, and the sale of power to ultimate consumers devolves on the Electricity Department of the Government of Orissa. These activities are co-ordinated to obtain full benefits for the region.

Transmission Lay-out

The present transmission layout is indicated in Plates 1 and 2 and consists of the following:—

(*i*) 160 route miles of single circuit 132 kV line from Power House I to Chowdwar with Substations at Chainpal (near Talcher) and Chowdwar (near Cuttack).

(*ii*) 100 route miles of double circuit 132 kV line from Power House I to Rourkela with substations at Jharsuguda and Rourkela.

(*iii*) 4 route miles of double circuit 132 kV line from Power House I to Aluminium Factory, the supply being metered at 132 kV at the Aluminium Factory in Hirakud.

(*iv*) 51 route miles of single circuit 132 kV line from Rourkela to Joda with arrangments for 66 kV take-off to other centres. In view of the importance of the loads at Joda, the question of constructing a second 132 kV line from Rourkela to Joda via. Bonaigarh area is being further examined.

(*v*) 59 route miles of single circuit 66 kV line from Joda to Kuldiha with substations at Noamundi (Bihar State) and Kuldiha.

(*vi*) 20 route miles of single circuit 66 kV line from Joda to Koira with substation at Koira is also proposed.

(*vii*) 26 route miles of single circuit 66 kV line from from Power House I to Bargarh with a substation at Bargarh.

Technical Features of Transmission Lines; Towers

All the 132 kV and 66 kV Transmission lines are carried on lattice steel masts. The supports are designed for wind pressure acting on 1½ times the exposed area of one face of the tower and two-thirds the projected area of each conductor. The wind pressure adopted for 132 kV lines is 20 lbs/sq. ft. except for the coastal belt from Dhenkanal to Chowdwar where 30 lbs/sq.ft. is assumed; the 66 kV lines are based on 15 lbs/sq.ft. wind pressure.

The factors of safety employed in the design of towers and cross arms are 2.5 under normal conditions and 1.5 under broken wire conditions. One top conductor or earth wire is considered broken for tangent and angle towers of single circuit lines and tangent and 5° angle towers of double circuit 132 kV. lines, while three conductors are considered broken on the same side for 30° and 60° angle towers of double circuit lines. For the tangent tower, the unbalanced pull due to the broken conductor is taken as equal to 75% of the maximum working tension of the conductor. For the dead-end towers, one middle conductor is considered broken for single circuit and three conductors broken on the same side for the double circuit towers.

Four different types of towers are used for each line. Details of the towers are furnished in Table 1 below: (vide also plates 3, 4 and 5).

The requisite number of tower extensions of 10 ft. were ordered from the manufacturers and the 30 ft. extensions required for the river crossings were fabricated in the Project work-shops. All extensions are separate panels which can be added to an existing tower of the normal type, thus facilitating alterations

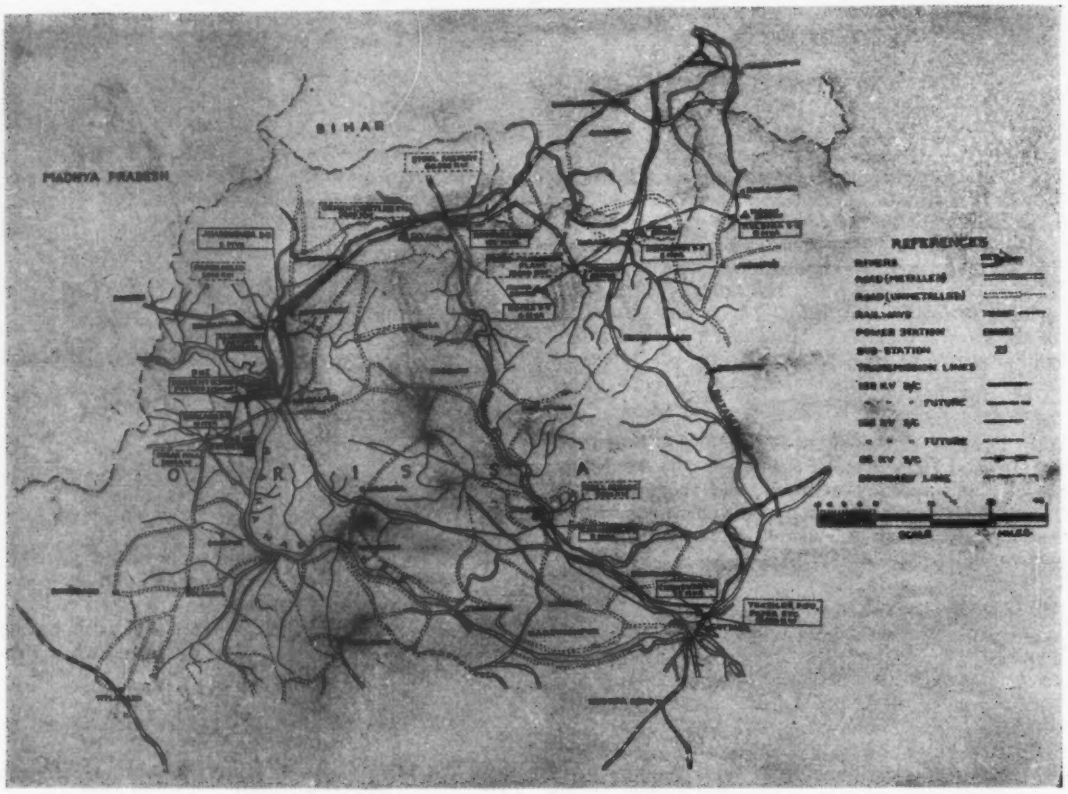


Plate 1— Geographical Layout of Transmission System.

to lines and minimising the number of spare parts which must be stocked in case of damage to towers.

The single circuit towers were supplied by M/s British Insulated Callender's Cables Ltd., and fabricated in India from standard steel sections. The cross arms and top portions of the tower were galvanized and the portions below the cross arm were painted with aluminium paint. Before starting mass fabrications, specimen towers of the A, A_1, B, B_1, P and Q types were tested to destruction at the Mettur Workshops of the Madras Electricity Department.

The double circuit 132 kV towers, fully galvanized and crucial members fabricated with high tensile steel, were imported from M/s. Societa Anonima Elettrificazione, Milano, Italy. In this case also, one specimen tower of each type was tested by applying test loads equivalent to the stresses specified multiplied by the corresponding factors of safety, to ensure that the design complied with requirements; one E type tower was also tested to destruction in the Company's universal test bed in Milano. This test shop is fully equipped with Electro-mechanical devices to control from a central cabin the application of loads and to give continuous readings of stress and deflection measurements. Although minimum thicknesses of 1/4″ for leg members and 3/16″ for other members were specified, the Company provided for members of thicknesses 6 mm. & 4 mm. respectively. Since such towers have been tried in other projects and as the tests in the works were satisfactory, these deviations were accepted. As will be clear from table I, a notable feature of these towers is the savings in steel effected by the use of high tensile steel for important members; two circuits could be carried on each support with but a slight increase in the total weight of the support.

The protective angle for the earth wire is generally 30° except in the case of angle and dead end towers for which it is 35°.

The design of foundations is based on an ultimate bearing pressure on soil of 2½ tons per sq. ft. ; and for 132 kV. double circuit towers uplift loads equal to the maximum produced by tower design loading plus 75% over load is assumed.

Conductors

The conductors for 132 kV lines are 37-strand Aluminium conductor steel reinforced with 30 strands of 0.118″ dia. Aluminium and 7 strands of 0.118″ galvanized steel, corresponding to the standard nominal copper area of 0.20 sq. inch. The conductors for the 66 kV lines are with 6 strands of 0.186″ aluminium, and 7 strands of 0.062″ or alternatively single strand of 0.186″ galvanized steel, corresponding to the nominal copper area of 0.10 sq. inch.

The earthwire for both lines is a 19 strand one with 12 strands of 0.110″ aluminium with 7 strands of 0.110″ galvanized steel corresponding to the standard nominal copper area of 0.07 sq. in.

Vertical separations between phase conductors vary

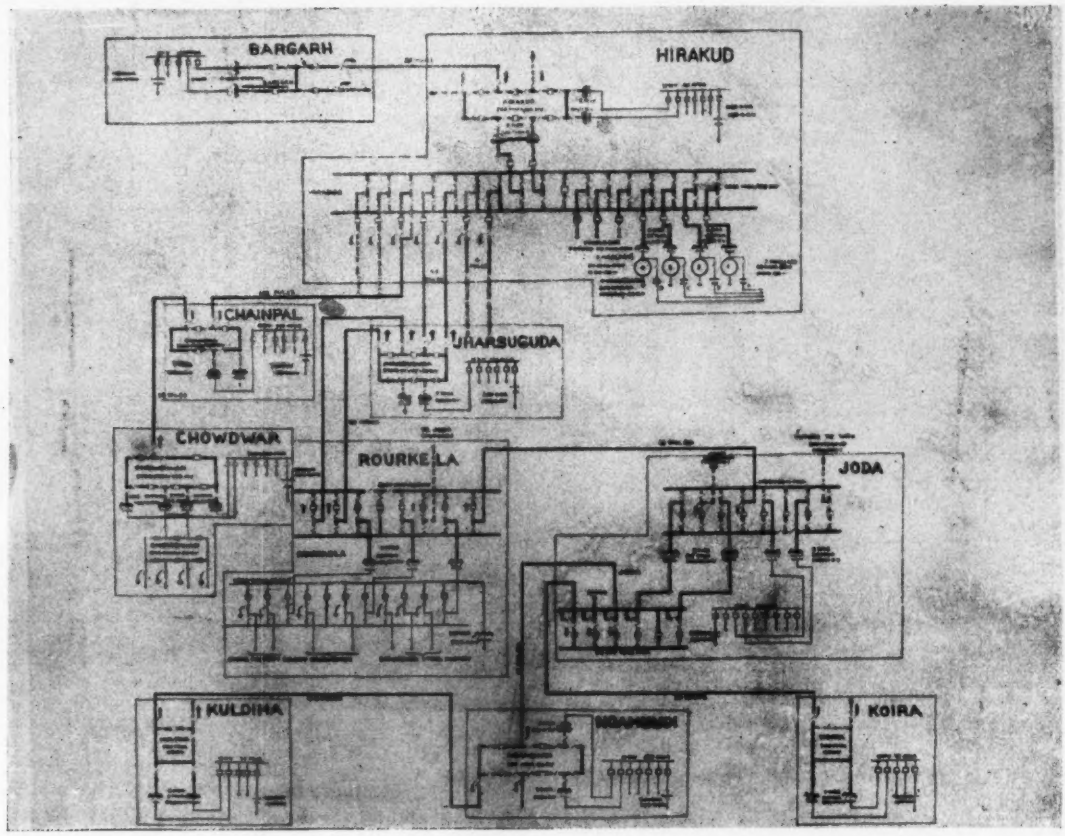


Plate 2. Schematic Layout of Transmission System.

from 13′-0″ to 14′-0″ for 132 kV lines and 6′-6″ to 8′-0″ for 66 kV towers; the horizontal separations vary from 21′-0″ to 25′-0″ and 13′-0″ to 16′-0″ for the respective voltages.

The phase and earth conductors have been generally strung with a factor of safety of 2.5 under conditions of maximum wind and minimum temperature; in the case of the 30 lbs. wind pressure region, however, factor of safety of 2.2 is adopted and for the earth conductor for 66 kV lines 3.5 has been allowed. The conductors were procured from M/s. The British Insulated Callender's Cables Ltd., M/s. The National Insulated Cable Co. of India Ltd., and M/s. Aluminium Industries Ltd., Kundara (T. C. State).

TABLE 2

Technical Particulars of Conductors.

		37/. 118	6/0. 186 7/0. 062	7/. 186″	19/. 110
Size and no. of wires.	Al.	30/. 118	6/0. 186	6/. 186″	12/. 110″
	Steel.	7/. 118	7/0. 062	1/. 186″	7/. 110″
Overall diameter in inch.		0. 826	0. 558	0. 558	0. 550
Nominal Secn. Copper equivalent.	Sq.in	0. 20	0. 10	0. 10	0. 07
Ultimate Tensile Strength.	lbs.	20,390	7385	8410	13200
Max. working tension. lbs.	20 lbs. region.	8160	2950	3360	5280 (6000 for 30 lbs. region and 3770 for 66 kVline
	30 lbs. region.	9270			
Weight of conductor per mile.	lbs.	3463	1403	1510	1972
Max. sag in still air at 140°F in ft.		24 for 1100 ft. span.	18 for 800 ft. span.	18 for 800 ft. span.	15 to 18′-0″ (for different spans & wind press.)

Jointing of conductor has been done throughout with a 100 ton hydraulic joint compressor unit, the joints being of the compression type.

In order to safeguard against vibration and consequent strand breakages, stockbridge vibration dampers have been installed at all strain locations, two numbers per conductor being used for longer river crossing spans. Bates dampers are standardised for suspension points.

Snail type clamps have been used for terminating the S.C.A. conductors on the angle and terminal towers. Recently, bolted crimped clamps have been ordered on M/s. Nippon Gaishi Kaisha Ltd., Japan through M/s. Kamani Engineering Corporation Ltd., and will be used on the Rajgangpur-Joda stretch of the

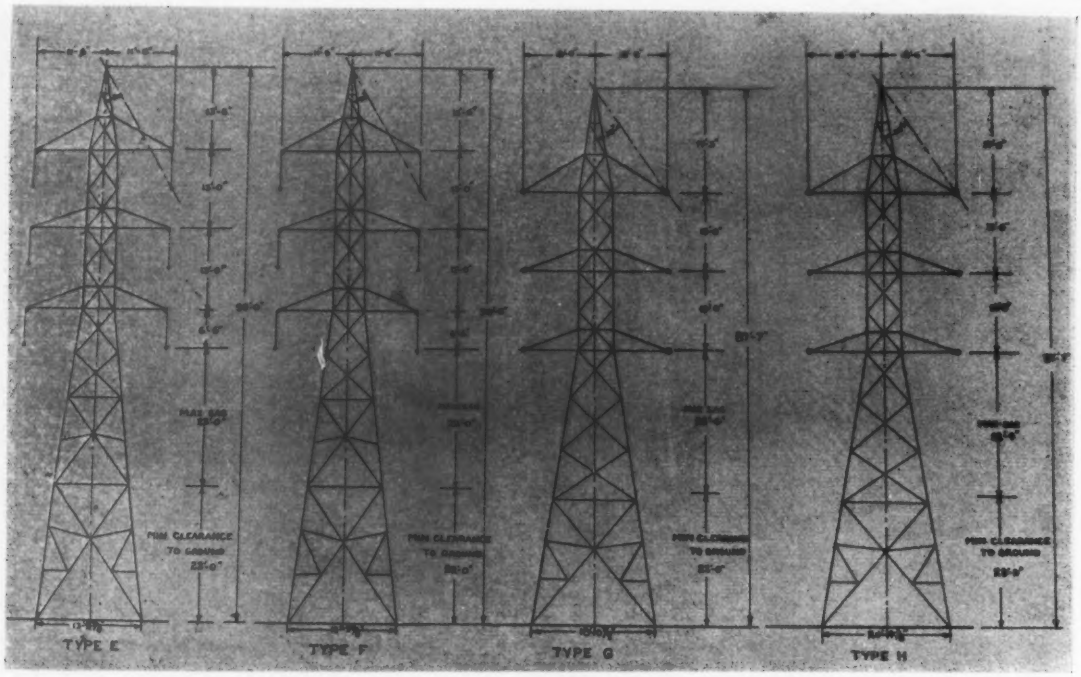


Plate 3— 132 kV. Double Circuit Towers.

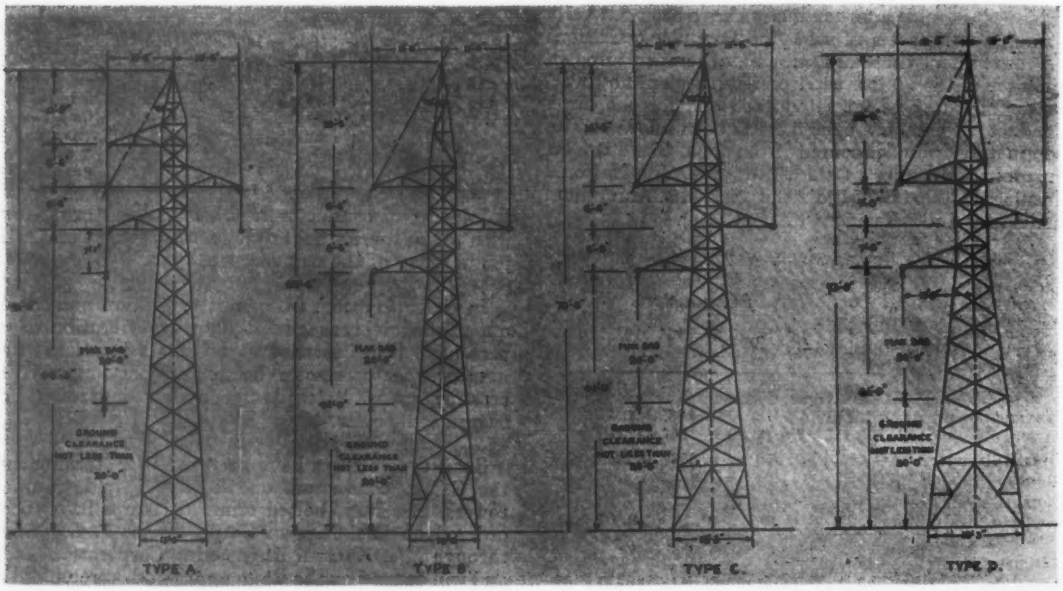
132 kV line. In both cases, jumper loops are joined with parallel groove clamps; the earth wires are connected to the tower with flexible copper bonds.

Suspension clamps are of the trunnion type with aluminium liners. It is specified that all suspension clamps shall slip at 75% of the maximum working tension of the conductor.

Insulators

The original supply of insulators for 132 kV and 66 kV lines were of the toughened glass type manufactured by M/s. Pilkington Bros. Ltd., England. Lately brown glazed porcelain insulators have been procured from M/s. Nippon Gaishi Kaisha Ltd., Japan. It is claimed by the suppliers of glass insulators that whenever a disc becomes defective due to electrical,

Plate 4— 132 kV. Single Circuit Towers.



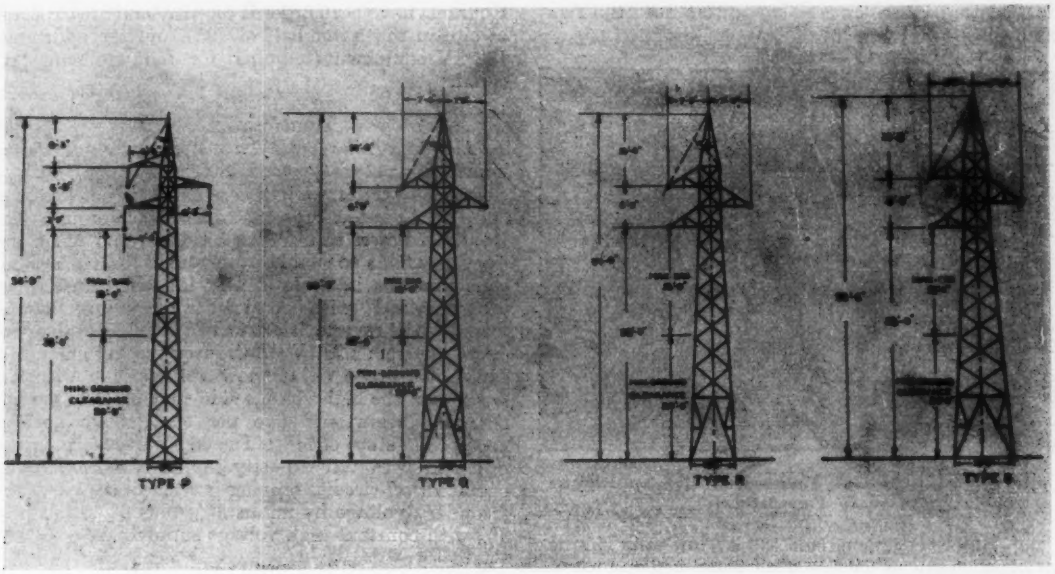


Plate 5— 66 kV. Single Circuit Towers.

thermal or mechanical causes, the glass is completely shattered and this eliminates the need for any testing of the strings in service. If the glass is visibly intact, the insulator must be electrically sound.

All insulators are of the Ball and Socket type. Suspension insulators are used for angles upto 2° and tension strings for larger angles. Double tension strings have been used for all railway crossings. Standard 10″ discs are used; 9 numbers for supension and 10 for tension strings for 132 kV lines and 5 units for suspension and 6 for tension for the 66 kV lines. Approach towers near the substations have reduced insulation, having either one disc less than specified above or reduced arc gaps. Arcing horns are generally fitted on line ends, except for the approach strings where both the line and earth ends are fitted with horns.

TABLE 3

Typical Technical Particulars of Insulators

	suspension insulator		*suspension insulator*	
	132 kv	66 kv	132 kv	66 kv
1. Outside dia. of disc.	10″	10″	10″	10″
2. Dist. bet. centres of Discs.	5¾″	5¾″	6¼″	5¾″
3. Electro-mechanical strength of each disc. lbs	10,000	10.000	25,000	10,000
4. Breaking load of complete string lbs.	15,000	15,000	37,000	15,000
5. Dry Flashover voltage of complete string without arcing horn	456 kv (9 unit) 380 kv (8 unit)	265 kv (5 unit) 225 kv (4 unit)	560 kv (10 unit) 520 kv (9 unit)	265 kv (6 unit) 205 kv (5 unit)
6. Wet flashover voltage of complete string without arcing horn	385 kv (9 unit) 355 kv (8 unit)	225 kv (5 unit) 185 kv (4 unit)	430 kv (10 unit) 395 kv (9 unit)	240 kv (6 unit) 190 kv (5 unit)

Safety Precautions

All the towers are grounded by means of 1″ dia. G.I. pipe 10 ft. long, driven inside the earth and connected to the tower by 0.1 sq. inch tinned copper tape.

Step bolts are fitted on one leg of each tower; enamelled "Danger" plate giving the line voltage and number plate giving the location number are mounted on each tower. Anti-climbing device will consist of barbed wire looped around each leg to a height of 10 feet.

Erection

The erection of all the transmission lines was undertakendepartmentally. Concretefoundations were generally used. Bolted type steel moulds were fabricated for each type of tower from 12 gauge m.s. sheets to facilitate concreting of footings. These could be dismantled the next day and used again for other towers. Separate gangs were organised for transport of concreting materials and tower members to each location, excavation, stub-setting, concreting, back filling, tower erection, insulator mounting and stringing.

About 30 miles of the 132 kV line from Rourkela to Joda is routed through Saranda forest in Bihar territory, infested with elephants and wild beasts. The materials for many tower locations had to be carried by manual labour as head loads over a difficult terrain. Approach roads had to be made for many of the tower locations which were not in the vicinity of the main forest road. As the road itself was impassable during monsoons, it had to be improved by constructing causeways, culverts and bridges over nullahs and mountain streams to facilitate construction and maintenance works.

Towers in the proximity of nullahs and waterways which carry torrential waters during the monsoons, have been carefully strengthened to withstand erosion. Special masonry foundations were constructed

for locating the river crossing towers near the right spillway. (*vide Plate* 6)

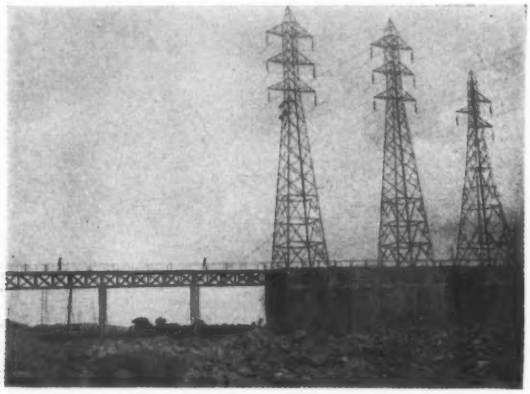


Plate 6. River crossing Towers near Right spillway on Masonry Foundations

80 miles of double circuit 132 kV line and 25 miles of single circuit 66 kV line were completed and towers for 160 miles of single circuit 132 kV line were erected in two working seasons. The rest of the work is programmed for completion before the onset of the monsoon in 1957.

Telephone Communication

Construction and operation of this vast net-work of lines would be difficult without proper communication facilities. A separate telephone line has been constructed from Hirakud to Rourkela and this will be extended to the outlying substations in this season. A telephone line from Hirakud to Bargarh is under erection. Between Hirakud and Chowdwar, however, Post & Telegraphs Department agreed to hire out a separate circuit erected on the existing telephone lines for the exclusive use of the Project, and this being financially advantageous was accepted.

Departmental telephone lines are carried on 50 lbs./yd. F. F. rails or "A" frames fabricated from 20 lbs/yd. rails. 10 SWG H. D.B.C. wire is used with maximum spans upto 250 ft. Portable telephones have been ordered to facilitate maintenance by hooking in at any intermediate place for contacting headquarters.

In addition to this, when the Substations are completed, carrier communication will also be available between Hirakud, Jharsuguda, Rourkela, Joda, Talcher and Chowdwar by utilising the H.T. line as main channels.

The routing of the telephone line through the Saranda forest presents formidable difficulties and hence the use of underground cables is under consideration.

Technical Features of Substations

The original siting of the Substations had to be rearranged to conform to the latest load requirements. 132 kV Substations are now being installed at Chainpal, and Chowdwar on the Cuttack line; and at Jharsuguda on the Rourkela line. 66 kV Substations are under construction at Bargarh, Joda, Noamundi Kuldiha and Koira. Subs ation equipments for Rourkela have been ordered recently and are expected at site in the latter half of 1957 and the additional 132 kV equipments required for Joda are being procured.

Transformers

All 132 kV and 66 kV transformers are of the oil immersed, natural cooled Star/Star type, with a closed delta tertiary winding of capacity not less than 30% of the rated capacity of the transformers. The Rourkela Power transformers will have 25 MVA tertiary windings to enable connections to synchronous condensers at later date. The 132 kV transformers are provided with on-load-tap-changing equipment with remote electrical control suitable for operation from a 220 V. D. C. supply so as to maintain constant voltage on the low voltage side with the voltage on the high voltage side varying from twenty per cent below and five per cent above normal, arranged in steps of $1\frac{1}{4}\%$. The 66 kV transformers are provided with full capacity tappings and externally operated off-circuit tapping switches to vary the secondary voltage by minus 3%, plus 6%, and plus 9% with constant high voltage supply.

Each transformer is provided with a double-float Buchholz relay.

The 132 kV transformers were originally specified for 650 kV impluse level, but had to be derated to 550 kV based on results of the type tests.

Switchgear

The equipments for 132 kV Substations at Chainpal, Chowdwar and Jharsuguda and the 66 kV Stations at Noamundi, Kuldiha and Koira were supplied by M/s. General Electric Company, England Ltd. while the 66 kV equipments for Joda & Bargarh are of the Siemens-Schuckertwerke make. The former have included conventional type bulk oil volume circuit breakers and the latter expansion type breakers.

Mesh system of bus connections has been adopted except for Rourkela and Joda where transfer buses are specified.

The 11 kV metering panels are equipped with an integrating watt-hour meter suitable for three phase unbalanced system, with an additional maximum demand indicator and time switch.

220 V. lead acid batteries are provided for all 132 kV Substations and 24 V alkaline tripping battery at the 66 kV Substations. To secure reliable carrier current communication facilities 350 ampere-hour batteries at 10 hour discharge rate have been found necessary for the former, while the corresponding rating for the latter is 25 ampere-hours.

100 KVA or 200 KVA station service transformers of ratio 11 kV/0.4 KV supply power for station facilities.

Protections

In addition to Buchholz relays, larger transformers are protected by balanced differential relays with back-up inverse time lag overcurrent relays.

The 132 kV feeders are equipped with carrier current protection with back-up overcurrent relays.

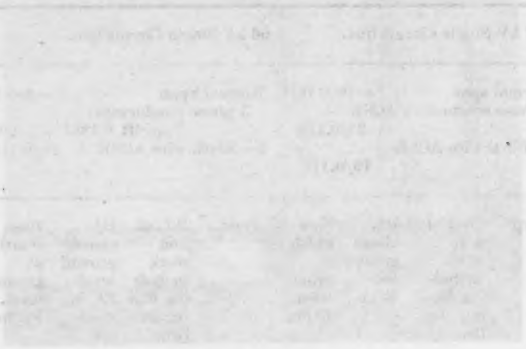
TABLE I

Tower Details

DESCRIPTION	132 kV Double Circuit line. Normal span =1100 ft. 6-phase conductors ACSR 37/0.118" 1—Earthwire ACSR 19/0.110.				132 kV Single Circuit line. Normal span =1000 ft. 3-phase conductors ACSR— 37/0.118 1—Earthwire ACSR— 19/0.110				66 kV Single Circuit line. Normal Span =800 ft. 3 phase conductors ACSR 6.186" +7/0.062 1—Earth wire ACSR 19/0.110			
	Type.	Wt. of iron work including footing in lbs.	Ht. above level. Ft. in.	Base width at ground level. Ft. in.	Type.	Wt. of iron work including footing in lbs.	Ht. above ground level Ft. in.	Base width at ground level Ft. in.	Type.	Wt. of iron work including footing in lbs.	Ht. above ground level Ft. in.	Base Width at ground level. Ft. in.
1. Towers for tangent locations and angles upto 2°.	E	6600	90 0	13 9.3/8	A A_1	6240 6680	73 0 ,,	13 6 ,,	P	3610	56 9	8 6
2. Towers for angles up to 5° with normal spans & upto 7° with 820 ft. spans.	F	7200	90 0	13 9.3/8								
3. Towers for angles upto 15° with normal spans and smaller angles with longer spans.					B B_1	6740 7410	69 6 ,,	14 0 ,,	Q	3890	54 9	9 6
4. Towers for angles upto 30° with normal spans and smaller angles with longer spans (These are also used at Ry. crossings with reduced spans to secure the minimum f.o.s. of 3 stipulated for such supports)	G	10500	87 7	18 10.7/8	C C_1	8370 8980	70 6 ,,	14 3 ,,	R	4530	54 9	11 0
5. Towers for angles upto 60° with normal spans and smaller angles with longer spans— These are also used for dead-ends.	H	14300	87 7	20 4.1/8	D D_1	10850 11450	73 0 ,,	16 3 ,,	S	6000	58 6	12 6

(Note A_1, B_1, C_1, D_1, relate to 30 lbs/sq.ft. wind pressure region)

Maximum spans used are at the river crossing locations, about 1557 ft. with G. & H. towers having 30 ft extensions on the right side and 1640 ft. with H type towers having 20 ft. extensions on the left side.



Both "telephase" carrier system supplied by M/s. General Electric Co. and "contraphase" supplied by M/s. Associated Electrical Industries (India) Ltd. have had to be installed in some stations, as the protection had to be co-ordinated with the step-up station at Hirakud Power House where the latter type is being installed.

The 66 kV feeders have distance protection. The 33 kV and 11 kV lines have inverse definite minimum time over-current and earth fault protection.

Civil Works

The construction and operation of the grid Sub-stations in these outlying places, necessitates extensive civil works for colony quarters and roads, water supply, sanitation etc.

Divisional headquarters are envisaged at Rajgangpur, Joda & Talcher; other places will have sub-divisional or other sectional offices to maintain and operate the electrical equipments. The Colony buildings at Chainpal, Chowdwar, Jharsuguda, Rajgangpur, Rourkela and Bargarh are substantially complete and the buildings at the other sites are under construction. The type of buildings in these Colonies are in general similar to those constructed in the main colonies at Hirakud and Burla.

Wells have been dug in Chainpal and Jharsuguda and overhead tanks installed; water supply arrangements in other colonies are in progress.

Although pan latrines are in use at present, underground sewers with septic tanks are proposed to be constructed in due course in these Colonies.

Loads

As already stated, considrable pessimism prevailed in the early stages of the Project regarding the load prospects in this area. Details of present assessment of loads are given below:—

TABLE 4

Load Expected on the Hirakud System.

	1960—61			
	M.W.	P.F.	L.F.	M.W. @ 100% L.F.
1. Hirakud Aluminium Factory	55	0.91	99%	54.5
2. ,, Local	2	0.80	60%	1.2
3. Jharsuguda	6	0.80	50%	3.0
4. Rourkela Steel Factory	60	0.80	80%	48.0
5. Rajgangpur	7	0.80	80%	5.6
6. Joda (Ferromanganese	18	0.95	90%	16.2
7 ,, Local	3	0.80	50%	1.5
8. Noamundi (mining loads)	5	0.80	50%	2.5
9. Kuldiha ,, ,,	3	0.80	50%	1.5
10. Koira ,, ,,	3	0.80	50%	1.5
11. Chowdwar	12	0.80	50%	6.0
12. Talcher	2.5	0.80	50%	1.25
13. Bargarh	3	0.80	50%	1.5
			M.W.	144.25

Load expected on the Hirakud System

In addition to these, the electrification of Rourkela-Lotapahar and Raj-Kharswan-Barajamda sections of the South-Eastern Railway is being seriously examined. If this matures, power up to an extent of 10 M.W. will be needed. Also, the ultimate requirements of the Joda Ferromanganese Plant is expected to be as much as 60 M.W.

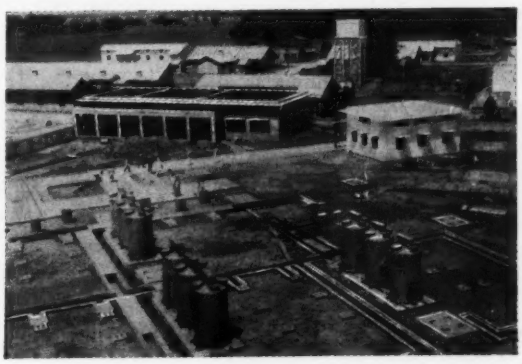
But the aggregate water potential of Hirakud I and Hirakud II Power Houses is estimated at only 127 MW which is far below the load demands in this area. This picture reveals that at no distant date additional generating capacity will have to be installed either by developing the Bhimkund hydro site on the Vaitarini River or by building a steam power station at Jharsaguda near the Rampur Collieries.

Network analyser studies have indicated that Synchronous condensers will be needed at Rourkela to minimise power losses and improve regulation. In order to cater satisfactorily to the enormous power requirements at Rourkela and Joda and to ensure reliable service, a third 132 kV line from Hirakud to Rourkela and a duplicate tie between Joda and Rourkela are under examination. This network of Grid lines is bound to grow and expand. We are still at the fringe of this vast development.

Conclusion

The advent of Hirakud hydro-power has already brought in its wake tremendous activity in the Orissa State. Villages which were sparsely populated are now teeming with workers—improving roads, building colonies and constructing factories. If it is realised that one kilowatt-hour unit is equivalent to ten units of human energy, it can be imagined how enormous will be the impact on the productive economy of the region by the release of massive blocks of electric power from Hirakud. There is no doubt whatsoever that an era of prosperity and plenty for the Orissa State has been heralded.

Plate 7. View of Jharsaguda Colony and Substation



(*Continued from page* 44)

The Hirakud Power System

influence over the eastern countries in time, the world would have been spared the two catastrophical wars. The lessons of the wars have sobered the western mind a great deal bringing about a realisation that the problem of the West cannot be separated from the rest of humanity and possible salvation for humanity lies not in internecine warfare but in recognising that there is only one problem for all mankind and that is to live comfortably.

It may be hoped that with this change, there will be more toleration and active help towards building our country and make up for a century of time lag in the development power and its utilization for human comfort replacing our erstwhile dull life into one of vigour, our petty jealousies and quarrels by kindness and toleration and above all our age old feudalistic outlook by democratic ideas.

With this new found joy and glorious life, let us hope that we shall contribute a good deal to a lasting peace for homosapiens ushering in an era of prosperity for the entire world and not for a narrow section of it.

(*Continued from page* 29)

Construction features of Hirakud Dam

(*b*) *Cross arm section.* Consists of a 3-foot long 1½ inch G.I. pipe to which a 3-foot long iron channel is welded at the centre point, This rests over the embankment and the 1½ inch iron pipe goes into the base section of 2 inch iron pipe.

(*c*) *Intermediate section.* is a 4-foot long, 2-inch iron pipe that connects the cross arm units.

Placing the cross arm section

Before the earth work is started on the embankment an augor hole of 9-inch dia is made to put the base section of 7-6″ long 2-inch iron pipe back filling around the pipe with clay is to be done after covering the pipe with one pipe cover.

When the embankment reaches the level of 3.5 feet above 2-inch foundation extension pipe previously installed, a hole of 3-feet deep, with base dimensions of 24″×42″ approximately is to be excavated. Then after locating the station an augor hole of 9″ dia is made upto the foundation extension to put the first cross arm.

With a great care the pipe cover is to be removed and the first cross arm is fixed with the foundation extension pipe with iron channel placing over the rolled area. The oakum or a cotton waste packing is provided in the joint position of 1½ inch to 2″ pipe not to allow any clay meterial to go inside the pipe.

Then the back filling is started around the 1½″ pipe below the iron channel by rod tamping. The filling is to be done after covering the 1½ inch pipe of cross arm by a pipe cover. After the back filling is properly done, covering the cross arm is started with typical embankment material in 4″ layers. At least 18 inch of material is to be compacted over the pipe cover of cross arms.

Succeeding cross arms will be fitted when the earth work is 6.5 feet over the previous cross arm elevation. These cross arms are fitted by adding 4 feet of 2-inch pipe in between the two cross arms. This will be continued upto the end.

Readings.

A set of readings is taken by lowering the torpedo with a steel tape down the entire existing installation each time an additional cross arm unit is installed. On the top of the 1½ inch pipe of the cross arm, levels are taken to know the elevations of the anchored sections of the lower cross arms by torpedo readings. When substracted from the reference points elevation, it will give the elevation of the respective measuring points. Comparison with the original elevations when the particular cross arm was fixed will show the vertical movement of the embankment.

If the set of cross arms are installed in one cross section then we can know hydraulic gradient by measuring water depths inside the cross arms.

Base Plate Installation

This installation is, in other way, known as foundation settlement installation. The apparatus is installed for detecting the vertical movement of the foundation with respect to the loading applied by the embankment. These are used where the foundation is semi-consolidated sand, silt or clay material as in Hirakud Island and Kolarikud Island.

Description.

The bottom portion of the installation is almost similar to cross arm apparatus, except that the channel of the first cross arm is welded with two plates of 12″ ×15″ and instead of placing the channel on the ground the two plates will be kept on the ground.

At 4 feet above the base plates, an anchor cross arm is placed to prevent the pipe column from sliding down into the base plate. The anchor cross arm is a 3-foot section of 5 pound channel, welded to a 4-foot section of 2-inch pipe.

To complete the installation, 4-foot sections of 2-inch pipe are joined by pipe sockets to extend the pipe to the surface of the embankment.

Surface Settlement or Movement Points Installation

These points are installed on the upstream and downstream slopes to record cumulative settlement of the surface of the embankment and horizontal deflection normal to the axis of the Dam.

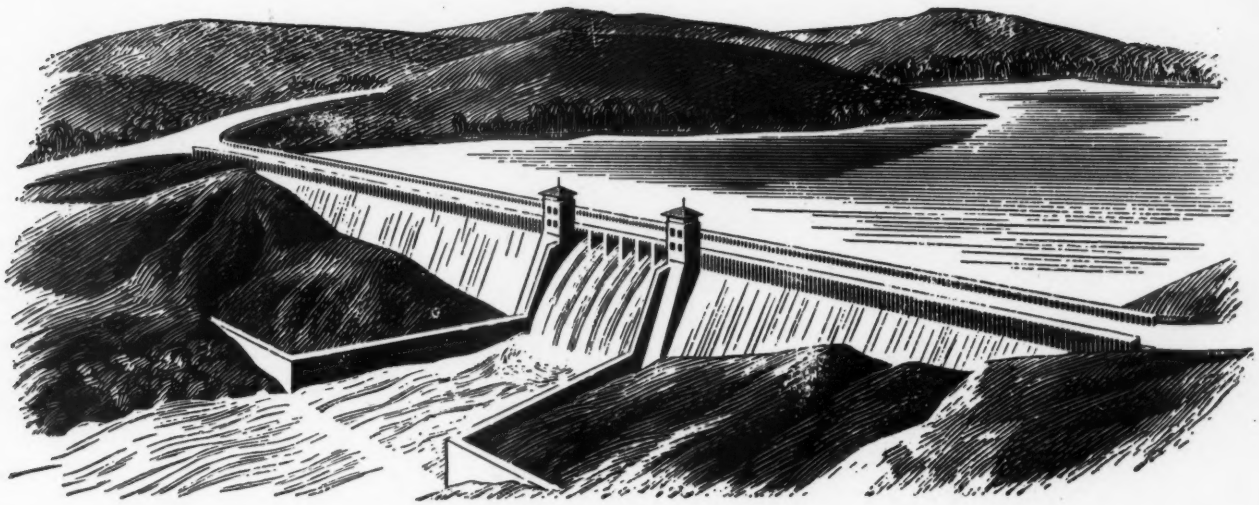
These points are 5-foot long ½ inch dia reinforcement bars driven into the embankment with a concrete cylinder of 12 inch and 6″ diameter.

When these are installed, measurements are taken from the distances in between rods and levels are also taken to know the settlement. From a particular known point, which is away from the Dam, angles are taken for horizontal deflection. By taking levels on the rods at certain intervals the settlement can be known.

CONSTRUCTION OF

KOYNA DAM

IN BOMBAY STATE



by

SHAH SALZGITTER & JOLLY PRIVATE LTD.,

198, CHURCHGATE RECLAMATION, JAMSHEDJI TATA ROAD, BOMBAY 1

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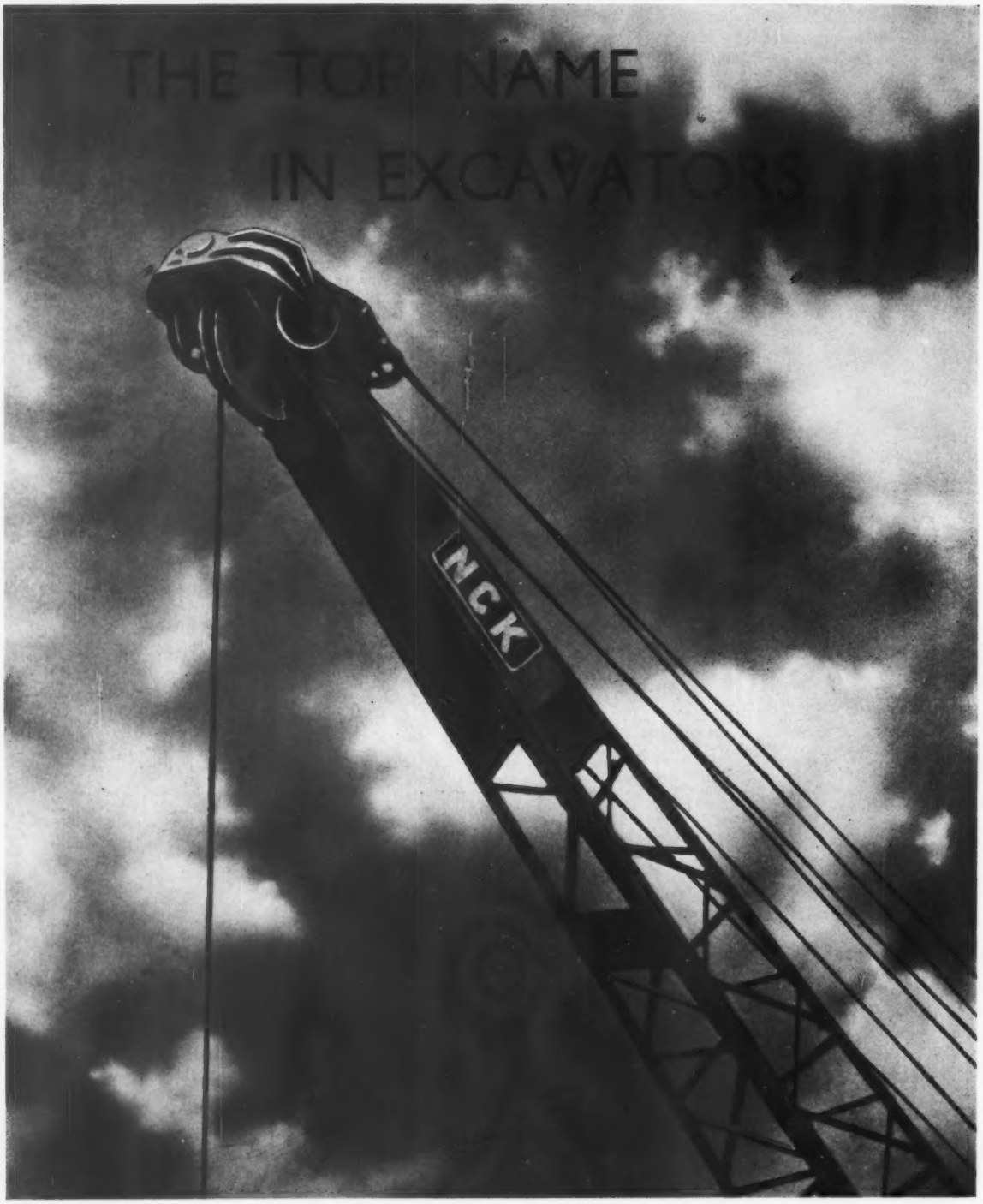

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The Canal System

By

S. S. BEHERA, B.C,E,, A.M.I.E.

Superintending Engineer, Mahanadi Canal Circle
Hirakud Dam Project

AUTHOR

The system of canals for irrigation forms an important factor in the Hirakud Dam Project for it will irrigate 6.71 lakh acres of land annually. It consists of 210 main canals and branches, 990 distributaries and minors and 1660 outlets. This contribution surveys the design and construction features of the canal system, including the Head Regulators, Cross Regulators, Cross Drainages, Aqueducts, Syphons, Falls, Escapes, etc. It draws attention to the problems of full utilisation of the irrigation waters that would be made available in the region.

On September 7, 1956 water for the first time was released from the Hirakud Dam Reservoir into the Bargarh canal. This marked the commencement of irrigation from the Project bringing in a new era in the development of agricultural economy of the country. This year irrigation will be extended to an area of about one lakh acres. The entire system is expected to be completed in 1958-59 when it will give much needed water to 6.71 lakh acres of land annually. Irrigation will thus play a very significant role in the Hirakud multi-purpose scheme. The following contribution gives an outline of the design and constructional features of the canal system.

General Description

The irrigation canal system extends to the two districts of Orissa, viz, Sambalpur and Bolangir-Patna. It comprises three main canals all fed by the Hirakud Reservoir. The total length of main canals and branches is 91.5 miles and that of distributaries and minors 460 miles. The system will have 2000 miles of water ourses for distributing water into the fields. Total number of structures involved in the system is as below:

1. Main canals & Branches	..	210
2. Distributaries & Minors	..	990
3. Outlets	..	1660

Besides the above, there will be over 30,000 one-foot stone pitched falls. 1660 pipe syphons and 1300 road crossings in the water courses

Right Side Flow Canal

Also known as Bargarh canal, it takes off at R.D. 28,800 of the Right Dyke at Sill+580.2. It has a length of 55 miles. It runs on contour for 48 miles after which it takes the ridge. Although designed and constructed for a maximum carrying capacity of 4802 cusecs at the head, the channel, due to the postponement of Lift canal, will be required to function for a maximum discharge of 3822 cusecs only with a full supply depth of 8.5 ft. commanding a culturable area of 3.8 lakh acres. The bed width at head is 150 ft. The Lift canal designed to carry a discharge of 980 cusecs and taking off at R.D. 114/500 was provided in the original scheme. But subsequently on financial consideration its construction was deferred. The canal, however, is constructed to accommodate the additional discharge of 980 cusecs in the event of the Lift canal construction being taken up at some future date.

Two branch canals and 21 distributaries are taken from the canal. The two branch canals viz., Attabira and Retamunda have a full supply capacity of 902 and 506 cusecs respectively. Of the distributaries :—

	14	have a discharge below	100 cusecs
	4	-do-	from 100 to 200
and	3	-do-	300 to 400

This being a contour channel, it crosses a large number of cross drainages which carry discharges varying from 100 cusecs to 38500 cusecs. Four of these viz. Danta, Girsul, Jira and Ranijhor are major rivers each carrying a maximum discharge of over 33000 cusecs.

Left Side Flow Canal or Sason canal

This canal takes off at R.D. 35/700 of the Left Dyke Gap IV at Sill+585.1. It is a contour channel in its entire length of 14 miles. The full carrying capacity at the head is 630 cusecs with B.W. 55 ft. and full supply depth 4.9 ft. commanding a culturable area of 62177 acres. The canal tails into two distributaries, Parmanpur and Homa Tail. The former is a ridge channel 12 miles long having a full supply discharge of 140 cusecs and the latter a contour channel 40 miles long wih a full supply discharge of 327 cusecs. Besides these two tail distributaries, there are six other smaller distributaries and a number of direct outlets taking off from the canal.

Sambalpur Canal

It takes off at R.D. + 484 of the Left Dyke Gap II at Sill + 576.5. Being a small channel with a full supply capacity of 120 cusecs only it is termed as a distributary. It has a length of 12 miles and it brings under command a culturable area of 11800 acres.

Capacity of Canals

The capacity of a canal is determined from the acreage it has to irrigate during the peak demand period and duty adopted for that period. At the initial stage of planning and designing it is not possible to prepare the detailed *chakbandi*. Consequently, it is difficult to assess accurately the culturable command able area at that stage. In tis Project, the following method was adopted to find out the gross commandable area and culturable area which formed the basis of working our capacity. It may be stated that figures thus obtained are tallying fairly well with the

Fig. 1.—Cross Regulator at R.D. 33/500 of Bargarh Canal. In the back ground is seen the Head Regulator for Attabira Branch. Designed for a full supply capacity of 902 cusecs, this Branch Canal was let in with water during September 1956 to provide irrigation for an area of 60,000 acres.

figures arrived at after the preparation of detailed *chakbandi*.

The alignments of the various channels along with their irrigation boundaries were marked on 4" to a mile topo sheets having contours at 5 ft. intervals. From this the gross commandable area was measured as accurately as possible. This was done by means of a planimeter. The next step was to find out what percentage of this area constituted the culturable area.

In the Revenue records available in the District Office, land classification is made under the following headings:

1. Culturable area
2. Garden
3. Forest
4. *Gochar*
5. Stoney
6. Water logged
7 Village roads etc.

The areas covered by each distribution system were taken from Revenue records under the various headings as shown above. 50% of the forest and *gochar* areas was assumed to be ultimately brought under irrigation. Accordingly 100 % of areas against items 1 & 2 and 50% of areas against items 3 & 4 represented the irrigable area. Areas against items 5,6 & 7 were left out as unculturable. From these the percentage of culturable area to the gross area i.e. total of items 1 to 7 was ascertained. Percentage thus worked out for different distribution systems was found to vary from 80 to 58.

The canals are expected to have Kharif intensity of 100 and Rabi intensity of 48%. With these intensities and taking into consideration the nature of soil and the existing agricultural practice in the tract, crop planning has been assumed as follows :—

	Kharif	*Rabi*
Paddy	70% of C.C.A.	33% of C.C.A
Sugar cane	10% -do-	
Cotton	5% -do-	
Other Kharif crops	15% -do-	
Cash Rabi, Viz. Wheat, Groundnuts, Potatoes etc		8% -do-
Light Rabi crops		7% -do-

The duties for different crops in different months are as follows :—

Crop	*Month*	*Duties.*
Paddy	July	100
	August	150
	September	100
	October	100
	November	120
Sugar cane	January to May	60
	June	65
	July to December	120
Cotton	June to December	300
	December to June	200
Wheat	December to March	200
Other crops	June to December	200
	July to April	200

From the distribution of crop and duties as above, it may be seen that maximum water requirement is in the month of July. The requirement of water during the month of July for 100 acre area is worked out as below :—

Crop	*Acres*	*Duty*	*Water requirement in cusecs*
Paddy	70	100	0.7
Sugar cane	10	120	0.083
Cotton	5	300	0.017
Other crops	15	200	0.075
	100 acres		0.875 cusecs

The water requirement obtained as above represents the requirement at the head of water courses. To this must be added the transmission losses through the channels in order to arrive at the capacity at canal head.

The transmission losses in distributaries and minors have been taken at 10% of the discharges of their offtaking channels and in case of canals it is taken at 8 cusecs per million sq. ft. of wetted area.

Fig. 2.—Plain concrete arch aqueduct 10 spans of 25 ft. each with granite stone masonry substructure over Ranijhor at R.D. 203/000 of Bargarh Canal. Its construction was recently completed at a cost of about Rs. 8 lakhs.

RESERVOIR

RIGHT

R.D. 1500

V.R.B
R.D. 46370

R.D. 33000

R.D. 69850

D.R.B.
R.D. 96500 R.D. 95000
R.D. 97500

R.D. 56400

RAIPUR NATIONAL HIGHWAY No. 6

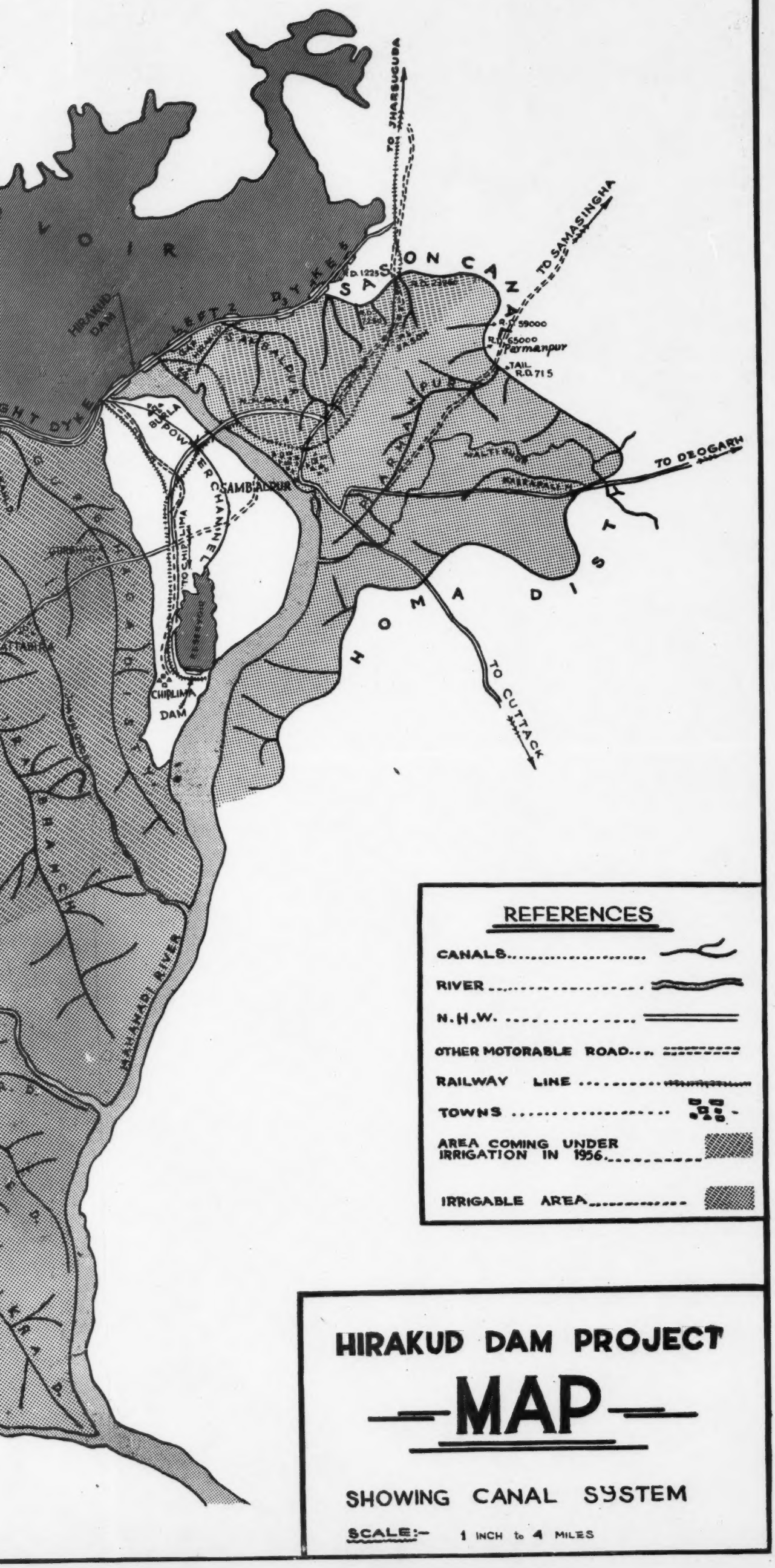
BARGARH

BARGARH DISTY

BARGARH

BARGARH

BARGARH



HIRAKUD DAM PROJECT

MAP

SHOWING CANAL SYSTEM

SCALE:- 1 INCH to 4 MILES

Design of canal sections

No rigid method is available for designing cross sections for open-channel flow. There are several formulas which apply to the design of sections in hydraulic flow. For an acceptable design judgement and experience have therefore to be depended upon to a very great extent. In this project at the earlier stage design was based on Lacey's theory with values of 'f' varying between 0.85 to 1.5. Lacey's formulas after slight modification stand as follows :

$P=\frac{2}{3}Q\frac{1}{2}$

$V = 1.15473\ (fR)^{1/2}=0.7937\times Q^{1/6}\times f^{1/3}$

$S = 0.0003759\ f^{2/3} / R\frac{1}{2}=0.0005469\ f^{5/3} / Q^{1/6}$

$R = 0.47247\ Q^{1/3} / f^{1/3}$

The silt factor 'f' propounded by Lacey is not only a function of the mean diameter of silt particles, but it reflects the whole physical character of the channel. Lacey supplied design diagrams based on his original formulas. But revised design diagrams worked out by the Central Designs Organisation on the basis of the above modified formulas have been used in designing canal sections.

For all main canals which run on contour, the value of Lacey's silt factor 'f' has been assumed as 0.85. The slopes have then been obtained from Lacey's 'f'—Q relationship graph and bed widths and depths from the Regime dimension diagram.

For designing such reaches of the canals which run on ridge as also distributaries, minors etc which are usually ridge channels, the value of 'f' has been adopted from 1 to 1.5. Where the ground slopes rapidly this value has been assumed as 1.5 and a value of 1 adopted in case of gently sloping ground. With 'f' thus fixed, the water surface slope is then det ermined from Lacey's regime slope diagram. As Lacey's section for low discharges gives a wide and shallow channel section the sections for these ridge channels were not taken from Lacey's dimension diagram. Instead the sections were adopted from Garret's "Hydraulic diagrams for the design of channels in earth by Kutter's formula" with value of N=0.0225 and slopes arrived at as above. Sufficient berms are however left to allow for future widening, if any, of the channel section to bed widths corresponding to Lacey's section.

To assess a correct value for the Lacey's silt factor is not an easy matter. The value of 'f' varies from 0.4 to 1.6 and fixation of a value for a particular channel has to be done more or less arbitrarily. This has resulted in the development of too high or too low a velocity ending in scour or silting of the channel. Approach to the design of channel sections was therefore subsequently changed. It is imperative that velocities in a channel should be non-silting and non—scouring. Kennedy's equation for non-silting and non scouring velocities is $V_o = 0.84\ d^{0.64}$ and velocities ranging from 0.9 V_o to 1.2 V_o have been successfully adopted in designing canal systems in the South.

So $V = 0.756\ d^{0.64}$ to $1.008\ d^{0.64}$ .. (1)

In regime channels the slope generally decreases with increase of depth. The slope varies with depth according to the relation $S=kd^{-0.8}$ to $KD^{-1.0}$

K,in this relation is taken about $\frac{0.6}{1000}$

So $S=\frac{0.6}{1000}d^{-0.8}$ .. (2)

The velocity is also a function of R & S. For convenience of applicability Manning's formula is used.

$V = \frac{1.4858}{n} \times R^{2/3}\times S^{1/2}$

Where n is taken as 0.0225.

The channel is designed as trapezodial with side slopes $\frac{1}{2}$: 1

So $Q = AV=\left|\frac{(b+d)}{2}\ d\right| \times \left|\frac{1.4858}{0.0225}\frac{\frac{(b+d)\ d}{2}^{\frac{2}{3}}}{b+2.24\ d}\right|\times S^{1/2}$ .. (3)

With Q known, the value of other three unknowns, viz. b, d & S can be found out. Based on the above three formulas, suitable practical depths are taken and the corresponding slopes fixed and within certain ranges of velocities corresponding to the depths from formula (1), the discharges and bed widths have been found out. Thus a table showing bed widths, grade, velocity and discharge has been prepared from which design is made. All subsequent designs of channels in this Project are being made on this basis.

Masonry Structures

The cost of all structures involved constitutes nearly 50% of the total cost of the system. Special and careful attention have been given to design the most suitable and economical type depending on the ground considerations and keeping in view the locally available materials as also skill of the labour.

Fig. 2.—One of the Distributaries Ex-Attabira Branch Canal which received water for irrigation during September 1956.

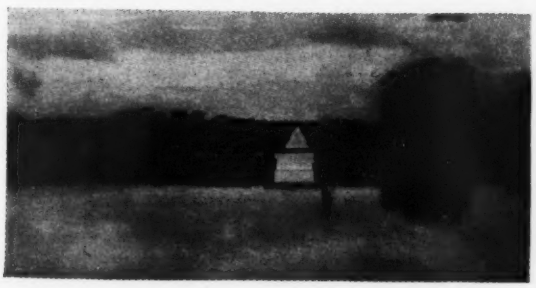


Fig. 4.—An Aqueduct on Bargarh Canal consisting of 5 spans of 10 feet each. The trough is of R.C.C. and a 12 feet. roadway is carried along side over arches on extended piers.

Good granite stone is available almost throughout the area. Extensive use of this material is therefore made in masonry. Next to stone, bricks have been used in masonry works to a great extent. A quartzite variety of stone is available in plenty almost all along the canals within a radius of one mile or so. Being readily available and of a slightly softer variety, it costs considerably less than granite. Advantageous use of this type of stone has been made in mass concrete in the foundation of structures. Use of reinforced concrete work has been kept to the minimum in order to restrict use of steel.

Head Regulators

These are designed either as a weir or an orifice. Depending upon the F.S.L. in the offtaking channel in relation to the bed level in the parent channel, the weir or the orifice has been treated for free flow or submerged conditions. The regulating arrangement in the weir type regulator is with two rows of karries and that in the orifice type is with gates with screw gear operation.

Cross Regulator

Eight cross regulators have been constructed in the Bargarh canal at an average interval of about 5 miles. All are combined with bridges. Some of the earlier designs provided for controlling arrangement with needles. This was however not considered to be satisfactory arrangement to effect the necessary control and raising up water lend in the upstream. Later designs have therefore been provided with gates operated by screw gears.

The cross regulators have been designed as a submerged weir having a cistern in the downstream for dissipation of energy. The needle controlled cross regulators 2 in number are having 15 ft. wide vents. In the other type, width of vent is restricted to 8 ft. in order to limit the size of the gate thereby enabling easy operation by screw gears.

Cross Drainages

The main canals and some of the distributaries being contour channels are crossing a large number of drainages. Due to the rolling nature of the country even many of the ridge channels cross a number of drainages in some intermediate reaches. Suitable cross drainage works at these points have been provided depending on the nature of the valley crossed. Some of these drainages are of regular drainage formation and some are mere with cultivated fields. No discharge observations covering a number of years for these drainages were available. Discharges had therefore to be based on catchments only. For catchments above 5 sq. miles, discharges have been computed from Dicken's formula $Q = CM^{3/4}$ with $C = 1060$ For lower catchments discharges, have been computed from intensity varying from 1.1 cusecs to 3 cusecs per acre, intensity increasing with decrease in size of the catchment.

Aqueducts

These have been provided where sufficient headway is available. In case of low drainage discharge as compared to the canal discharge, under tunnel designed as an open culvert for full width of canal is provided. Where the drainage discharge is high compared to the canal discharges, the cross drainage has been designed as a flumed aqueduct.

The superstructures of the aqueducts have been designed either as R.C.C. or masonry troughs. Masonry trough is provided where there is an arch substructure. In other cases R.C.C. trough is provided. The sectional area of the trough has been fixed taking into consideration a maximum velocity of 5 ft. per Sec. through the trough. Where sufficient headway above M.F.L. of drainage is available, the bed of the trough is depressed to have maximum fluming within economic and practical limits. The flumed trough is connected to the normal section of the canal with an upstream splay of 1 : 3 and downstream splay of 1 : 5. The flumed entrances and exits have been lined with concrete or pucca stone pitching. Besides, masonry canal wing walls have been provided both at the upstream and downstream side of the trough for safety and to facilitate bank connections.

In case of costly foundations, where R.C.C. trough has been provided, the span is kept 25 ft clear and the trough divided into compartments. The side and intermediate walls of the trough are designed as beams supporting the slab at the bottom. A 12 ft. wide inspection path is carried over one of the side vents of the trough. Where better foundation conditions are available, the span is kept 10 ft. clear with a slab spanning directly and the side walls designed as R.C.C. cantilevers. In this type, the 12 ft. wide inspection path is carried by the side of the trough over concrete arches resting on the piers.

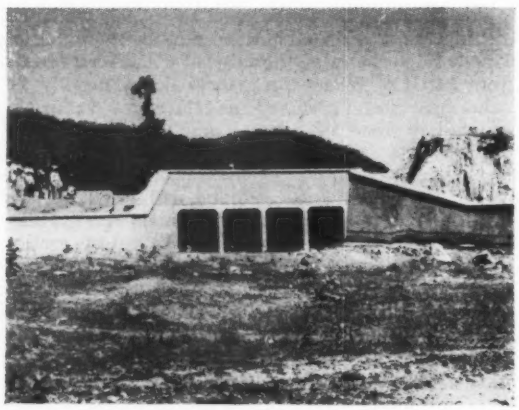


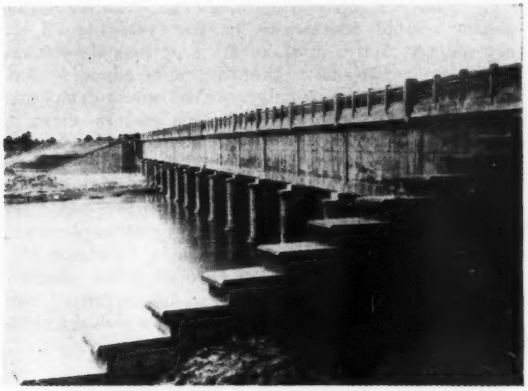
Fig. 5.—A four-barrelled Syphon on Bargarh Canal.

The foundations of the aqueducts fall mainly under three categories depending on foundation conditons:

1. Well type foundation for piers and abutments have been adopted where no good strata was available at considerable low depths. The wells adopted are of plain concrete with nominal reinforcements. In such cases span adopted is 25 ft. clear.

2. Where good strata consisting mostly of disintegrated rock was available at shallow depths, plain concrete raft foundation from abutment to abutment with cut off walls at upstream and downstream of the drainage has been adopted. Span is kept 10 ft. clear in these cases.

3. Where good rock strata was available within reasonable depths, open foundation has been resorted



R.C.C. Aqueduct consisting of 14 spans of 25 feet each over river Danta at R.D. 69/000 of Bargarh Canal. Built at a cost of nearly Rs. 17 lakhs, the aqueduct is now under test.

to and superstructure designed as plain concrete arches of 25 ft. clear span.

In all these aqueducts abutments, wing walls, returns, etc are built in coursed rubble masonry.

In case of small channels crossing fairly wide drainages, Hume pipe aqueducts resting on masonry piers have been provided.

Syphons

In most of the canals and major distributaries, drainages have been syphoned and channels allowed to flow freely. In case of minor distributaries where the drainage discharge is considerably higher compared to the discharge of the distributary, the channel is syphoned, within permissible limit of head lost through the structure.

Generally all syphons are designed as barrels with maximum permissible velosity of 8 to 10 feet sec. in the barrel. In the earlier designs, R.C.C. box type barrels were used but due to constructional difficulties and slow progress in execution, subsequent designs were changed to masonry side walls with R.C.C. slab on the top.

Incidentally, a large number of 6′ dia Armco pipes was available from Disposals and these were made use of in forming syphon barrels. The Armco pipes are encased in plain cement concrete with nominal reinforcements. This use helped a good deal in speedy execution.

For small discharges where the smallness of the barrel does not allow sufficient working space inside, R.C.C. Hume pipes are used as barrels.

The head walls, wing walls etc of all syphons are either of stone or brick masonry.

Where the bed of the drainage is having a steep slope, a fall (Drop wall) is provided at the upstream of the syphon. The clearance between the soffit of the barrel and top of the downstream curtain wall is kept to a minimum of 3′ or half the height of the vent whichever is less in order to prevent choking of the barrel by the incoming sand and git. Where the downstream ground level is higher than the downstream curtain wall, a tail channel is invariably cut for proper functioning of the syphon.

Falls

No falls are required in the main canals and some of the distributaries, as they run on contour. The number of falls required on the channels running on ridges is however numerous due to the rapidly sloping nature of the country. At places the ground falls is as high as 20 ft. to 25 ft. per mile. In order to effect economy to the maximum extent possible, some simple and cheap type falls with locally available materials have been made use of especially for small discharges and low drops.

The following types of falls have been adopted in this Project :—

1. Glacis type.
2. Vertical falls with notches.
3. Well type.
4. Skin type.
5. Rock cascade type.

Glacis type

This type has been used for discharges over 40 cusecs and drops over 3 ft. The glacis is designed with slopes 3/4 : 1 & 2/3 : 1. Downstream baffle and cistern are provided for dissipation of energy on the principle of standing waves. Fluming to a maximum extent of 66 % is resorted to when found economical.

Vertical falls

Vertical falls with notches have been adopted for discharges upto 600 cusecs for low drops. This type has the special advantage of maintaining the upsteam supply level with varying discharges in the channel.

Well type falls

This type is suited for small discharges with comparatively high drops. They have been adopted for drops from 6 ft. to 12 ft. with discharges upto 40 cusecs. This type generally provides a well in the upstream connected to the downstream by means of Hume pipe. Ordinarily a well is also provided at the downstream. Most of the energy is lost in overcoming the friction through the pipe. This is quite a cheap of fall and incidentally provides for a crossing across the channel with a nominal extra cost. The cost of construction of one 10 ft. fall with a discharge of 32 cusecs combined with a V.R.B. comes to Rs. 4200/- against Rs. 6100/- for a Glacis type fall for similar conditions.

Skin type fall

This type is suited for discharges upto 40 cusecs and drops upto 6 ft. It is designed on the same principles as a Glacis type, difference being that the Glacis in this case is in a slope 4 to 1. Its construction is however very much simpler and it is also much more economical. The glacis and the cistern are generally constructed with one foot thick masonry or concrete. The cost of a fall of this type is Rs. 1400/- against the cost of Rs. 3570/- of a Glacis type for a discharge of 37 cusecs and drop 6 ft.

Rock cascade type

This is yet another very cheap type of fall suitable for low discharges. This type has been adopted for discharges upto 15 cusecs and drops upto 6 ft. The

principle of design is same as per Skin type fall except that the glacis is made in a slope 8 to 1. The entire structure is made with one foot dry rubble stone pitching with cement mortar grouting. This type with simply dry rubble pitching has been extensively used in the water courses.

Bridges

Bridges have been provided at all crossings of channels in the existing roads. They are designed to conform to the standard of the existing roads. Where only an existing track is crossed, a bridge conforming to the standard of village road is provided. All bridges have been designed as per I.R.C. standards. Where a road is crossing a channel in deep cutting and sufficient head room is available, arch bridge has been adopted. In other cases R.C.C. decking has been provided. The substructure in all cases is either of stone or brick masonry. In some of the earlier designs, cement concrete block masonry with cement concrete hearting has been adopted.

Escapes

Two escapes have been provided in the Bargarh canal. They are designed for 2/3rd supply discharges of the canal. They have been provided with regulation gates operated by screw gear arrangements.

Utilization of Water

Water for irrigation in a multi-purpose scheme is obtained at a very high cost. In this project the capital cost of a cusec of water inclusive of the cost of allocation of the dam works out to about Rs. 32,500. Such being the case,it is of utmost importance that planning is done sufficiently ahead to ensure that maximum benefits from irrigation are obtained as soon as the scheme starts functioning.

Two important factors which are likely to affect utilisation of water and consequently defer return on capital outlay so far as the Hirakud Project is concerned are :

1. Delay in construction of water courses for conveyance of water into the fields.

2. Lack of cooperation from the argiculturists to change over to the new system.

The present prevalent practice is that construction of water courses is left to the cultivators themselves. This is not a very satisfactory arrangement as it has been the experience in more than one project that non-construction of water courses has greatly delayed utilization of water. In this Project the water courses are being excavated by Government. This is quite a unique step taken to deliver water into the cultivators' land thus enabling speedy utilization of water and realisation of benefits and financial returns.

For this purpose land is being acquired and water courses excavated by Govt. down to 50-acre blocks. The excavation below 50 acres is left to the cultivators. The total length of water courses to be constructed is about 2000 miles. The cost of construction will be between Rs. 15/- to Rs. 20/- per acre of C.C.A. including cost of land. The cost is to be recovered from the ryots in easy instalments spread over a number of years.

To make the agriculturists change over from the existing age-old practice to the new system is not an easy matter. Many of them are sceptical about this change over. They have therefore to be educated and convinced about the usefulness of the new crop pattern and agronomic practice. With this end in view, a number of demonstration agricultural farms have been set up by Govt. in suitable central areas. The object of these farms is to teach the ryots by actual demonstration improved methods of farming under perennial irrigation, use of improved agricultural implements for different crops, use of better seeds, fertilizers etc. It is hoped that the ryots through these demonstration farms will readily take to the improved and intensive methods of farming without which development of irrigation will not meet with any success.

Programme & Progress

The entire canal system is estimated to cost about Rs. 687 lakhs excluding cost of land. Out of this. expenditure to end of August '56 is about Rs. 467 lakhs. The balance of Rs. 220 lakhs is programmed to be spent during the next three working seasons.

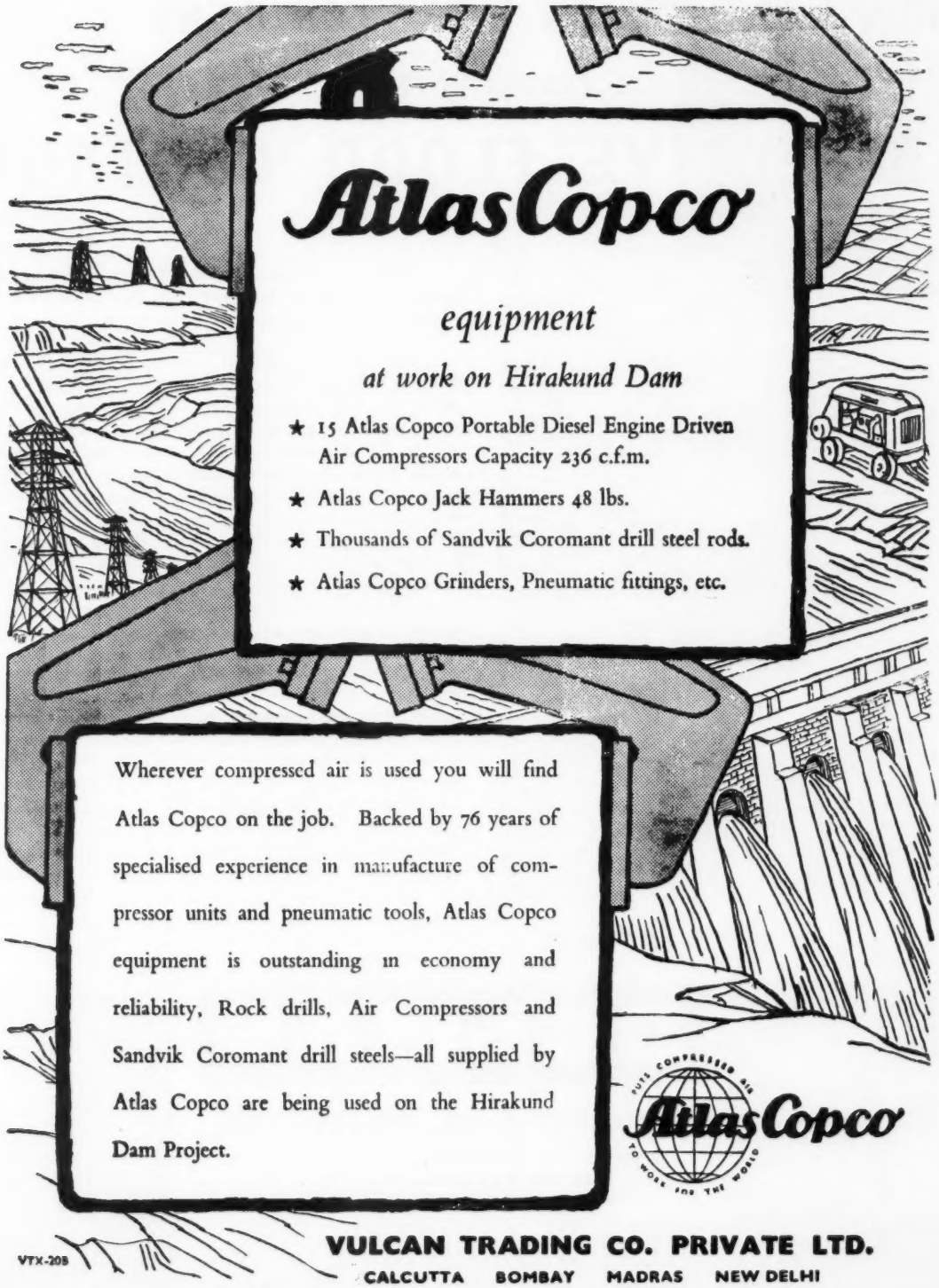
Progress on both earthwork and masonry structures has so far been satisfactory being ahead of schedule. The entire canal system is programmed to be completed by September 1959. Earthwork in the main canals and branches done up-to-date is 4570 lakhs cft against the estimated quantity of 5200 lakhs cft. Balance of 630 lakhs cft is programmd to be completed during the next two working seasons. Quantity achieved in distributary and minors so far is 1335 lakhs cft against 2270 lakhs cft estimated. The balance quantity of 935 lakhs cft is scheduled to be done during the next three working seasons.

Of 210 masonry structures in main canals and branches, 124 are completed and the balance 86 in progress which is expected to be completed by June 57. The distributary and minors have 990 structures of which 245 have so far been constructed and 158 in progress. Balance structures inlcuding those in progress are programmed to be completed by September, 1959.

For distribution of water into the fields narly 2000 miles of water courses are required to be constructed. Out of this, 465 miles covering an area of 1,12,000 acres have so far been constructed. This has involved in the construction of 375 outlets, 7000 falls, 315 pipe syphons and 330 road crossings.

Conclusion

With the commencement of irrigation this year the canals have already started yielding fruit. The construction of the system is in advanced stage of progress and entire scheme inlcuding water courses is expected to be completed in all respects by September, 1959 when the full area of 4.54 lakh acress will be brought under irrigation. The extension of irrigation to these areas will transform Sambalpur and Orissa into a rich prosperous agricultural area increasing production manifold which will add considerably to the food wealth of the country. The additional income and consequential economic benefit to the people will no doubt be very substantial.


Atlas Copco
equipment
at work on Hirakund Dam
★ 15 Atlas Copco Portable Diesel Engine Driven Air Compressors Capacity 236 c.f.m.
★ Atlas Copco Jack Hammers 48 lbs.
★ Thousands of Sandvik Coromant drill steel rods.
★ Atlas Copco Grinders, Pneumatic fittings, etc.
Wherever compressed air is used you will find Atlas Copco on the job. Backed by 76 years of specialised experience in manufacture of compressor units and pneumatic tools, Atlas Copco equipment is outstanding in economy and reliability, Rock drills, Air Compressors and Sandvik Coromant drill steels—all supplied by Atlas Copco are being used on the Hirakund Dam Project.
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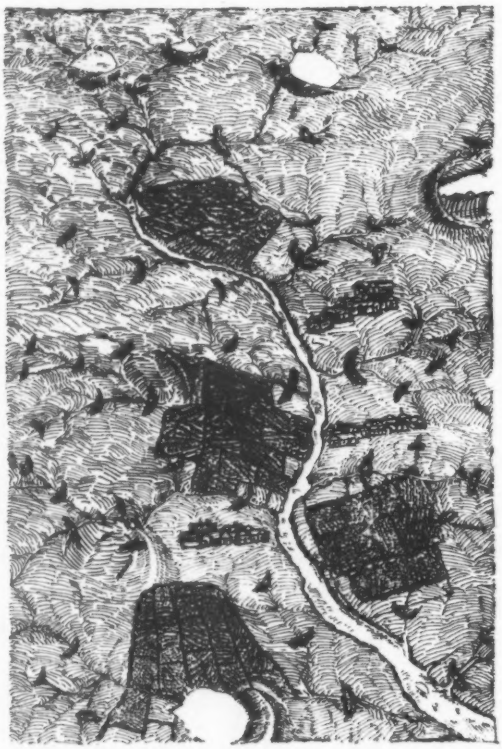
EFFECTIVE FLOOD CONTROL



Every year in some districts of India, the floods leave behind, ruined villages, destroyed crops, dead cattle and millions of people have to face the brunt of starvation and insecurity.

But our Government has worthily shouldered the responsibility of checking this scourge completely within the next few years. Soon the devastation by floods will be a calamity of the past. The teaming villages, will once again emerge into a permanent and vitalising security. One of the major schemes adopted by the Flood Control Board of India is to tackle the flood problem at the very root. Catching the rain drops where and when they fall is the only infallible way to prevent the flooding of rivers. This is best achieved by constructing small earthen bunds at the very sources of the water streams that feed the rivers. The construction of small earthen dams is not only much more effective but also more economical than building of large dams across the main rivers.

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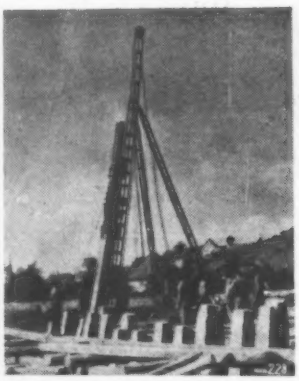

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Resettlement and Reclamation at Hirakud

By

S. S. MURTHY, I.A.S.

Deputy Commissioner and in charge of Hirakud Land Organisation, Government of Orissa.

AUTHOR

The complicated and protracted task of land acquisition, land reclamation, resettlement and evacuation in the Hirakud project was undertaken by the Orissa Government itself. To discharge this responsibility it set up the Hirakud Land Organisation. The following brief note gives an idea of the extent and the nature of the work and of the performance. The vastness of the job can be imagined if one remembers that it involved 18,000 displaced families resident in 183 villages, and 1,82,590 acres of land that will be submerged, the greater part of which is cultivable

The construction of the Hirakud Dam across the river Mahanadi about 10 miles from Sambalpur in Orissa results in the submersion of 249 villages (either partly or fully) situated in Orissa and 34 villages situated in the State of Madhya Pradesh. On account of the submersion, nearly, 18,000 families will be displaced and 1,82,590 acres of land will be submerged of which, 1,23,303 acres is cultivable land.

The Hirakud Land Organisation is a department of the Government of Orissa started for resettlement of these displaced persons. It is the responsibility of this organisation to acquire the properties submerged and to pay compensation, to reclaim sufficient lands for resettlement of the submerged-area people and to implement schemes to resettle them, as far as possible with the same facilities as they enjoyed in the area submerged.

Land acquisition

Upto the end of July, 1956, Rs. 617.24 lakhs was offered as compensation for private properties in the submersion area and Rs. 396.69 lakhs of it has been paid. Offer of compensation has been finished in the entire submersion area and payment of compensation by and large in the evacuated villages is also finished. However, cases in which compensation offered is disputed and cases in which rights of individual parties are in question are still outstanding for payment. The Madhya Pradesh Government is also taking steps for offer and payment of compensation to 34 villages situated in Madhya Pradesh.

Land Reclamation

In 1949, reclamation of forest area was taken up on a large scale for resettling the cultivators of the submersion area. By 31-8-56, 10,221.03 acres of land have been reclaimed fully. Out of this area, 3,800 acres of land have been settled with the submerged-area people and an area of 6,421.03 acres is still in the hands of the Hirakud Land Organisation for such resettlement. Of the reclaimed area, 4,700 acres of land have already been provided with irrigation facilities and other irrigation works are in progress. The irrigation works and the development works in these reclamation centres were done under the technical guidance and supervision of the Development Division of the Construction Organisation. 1,419 amillies of the submersion area have been resettled on the reclaimed lands. Tahle I will show camp by camp the number of villages formed and the number of families settled in each of such villages.

Resettlement

In the reclaimed area, villages have been regularly laid out and roads have been made connecting such villages with each other and all of them with the nearest main road. Wells and tanks for drinking water, schools for education of the children and Bhagbat Ghars for communal entertainment have been constructed in these villages. Grain golas have have been started for supplying rural credit and market sheds have been constructed. In one group of camps, a hospital has been constructed and the health of the resettlers in the rest of the camps is looked after by a medical officer stationed at Sambalpur with the help of a mobile van.

House sites are given free in these reclaimed areas and timber is supplied at 60% of the normal royalty for the construction of their houses. Manures and fertilisers are supplied free of cost and seed paddy is given on loan. An Agricultural Development Officer with staff constantly tours these areas and looks after the reclaimed lands and cultivation in general. Table II will show the development works executed in all these camps upto date.

Other schemes for resettlement

Besides reclaimed lands, 6,500 acres of canal irrigable and cultivable waste land have been surveyed and offered to the submerged area people for resettlement. The response to this resettlement from the submerged area people is, however, poor.

Periphery Settlement:

During this year's evacuation, the people living in the villages of the higher ridges preferred to shift to places above the maximum reservoir level (632 R.L.) and settled there, So, 62 villages were laid out and 3,150 house sites were allotted to these people dring the year 1956. A programme of development works for these villages has been drawn up and will be implemented during the year, 1956-57. It is expected that about 20,000 acres of submerged land will come out of the reservoir by the months of January and February every year. It is proposed to lease out these lands to the people who have settled

on the periphery. With this object in view, survey operations are being taken up and and all preliminary works for leasing out the periphery lands will be finalised in time to lease out this area to the people for the next cultivating season.

Cooperative farming:

For the resettlement of landless labourers, steps are taken for forming two cooperative farming societies as pilot scheme. These schemes are under the active consideration of the Government and it is expected that they will be implemented during the next cultivating season.

(*vi*) The people of the submersion area who have neither settled in the reclamation centres nor on the periphery have by and large purchased lands in other old established villages and resettled by personal efforts. As far as possible, statistics of such resettlement have been maintained by this organisation. Wherever such lands were available for sale, information was collected and published in the submersion area to enable the people to purchase lands. As royati land was made saleable by an amendment to the land laws in 1953, the people of the submersion area were enabled to purchase such lands and this helped resettlement substantially. It is on account of this that demand for reclaimed area was not as much as was expected.

Evacuation

This organisation started evacuating the submersion area on the requisition of the Construction Organisation from 15th April, 1955. During the year, 1955, 33 villages fully and 13 villages partly consisting of about 4,000 families were evacuated. Transport was supplied free of cost to the submerged area people for carrying all their movables excepting straw. The people were allowed to take house building materials obtained by breaking the houses even though they were all paid for by the Government. Free transport was not, however, given for this purpose. During 1956, 72 villages fully and 22 partly consisting of 10,352 families have been evacuated in the same manner. The total amount of money spent for these evacuation operations by the Government of Orissa is about Rs. 17 lakhs. Still, 2,000 families are living in the higher reaches and evacuation of 36 villages fully or partly will be necessary during the year, 1957.

The people of the submerged area have given utmost cooperation during the very difficult period of evacuation and due to this constructive attitude of the people, evacuation could be done peacefully and in time.

Table II

List of Development Works done in the Reclamation Camps.

1. *Irrigation works*	
Katas (Big Water Reservior)	49
Munda (Small water reservior)	28
2. *Water Supply Projects*	
Tanks	19
Wells	24
Water Tanks	3
3. *School Buildings*	
M. E. Schools	2
M. V. School for Girls	1
Lower Primary Schools	9
Temporary quarters for M. E. School Teachers	6
Temporary quarters for mistresses of V. M. School for Girls	6
4. *Hospital and Staff Quarters*	
Hospital	1
Quarter for Doctor	1
Quarter for Compounder	1
5. *Other Buildings*	
Community centre	1
Bhagabatghar	15
Debtagudi	7
Deraghar	3
Mahima Temple	1
Market Shed	2
Grain Gola	1
Roads	25 miles.

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Facing page 60

Statement showing the Resettlers living in the Reclamation Camps.

Name of Camp	*Name of settlements*	*No. of families settled*	*Total population.*
JHARGHATI	Rampella	137	600
	Mangalpur	97	394
	Kasipali	61	206
	Pitapali	31	129
		326	1329
SILAT	Batimunda	42	200
LARASARA			
LAMAL	Nimaipalli	28	122
	Goudpali	30	104
	Khurigan	38	154
	Dongripali	5	16
	Palsapalli	4	10
		105	406
GOUDPALI "B"	Baghra	11	45
BADSAHIB CAMP	Saplohara	27	133
	Kulsar	102	404
	Balanda	53	162
		182	799
SANKUNDESARA	Burda	39	154
	Khurrigan and Jalahari	4	10
	Belanda	7	22
	Kasipali	5	9
	Padhanpalli	15	53
		70	248
CHHAMUNDA	Burda	22	106
BASIAPARA "A"	Bartang	9	38
	Chilantikud	15	84
		24	122
BASIAPARA "B"	Phuljharan	10	
	Camp Proper	36	216
		46	
SANGRAMAL "A"	Kudopali	77	314
	Salpali	33	158
	Tihura	78	246
	Rasiapalli	41	192
	Haldibahal	31	161
		260	1071
SANGRAMAL "B"	Mura	93	416
	Kalmi	27	111
	Haldi	21	82
		141	609
SARDHAPALI	Sardhapali	71	306
LAMDUNGRI	Gujatal	53	207
	New Jamda	28	112
	Sahajbahal	25	132
	Silipathar	24	95
		130	546

Total—1419.

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High Pressure Grouting at Hirakud Dam

By

R. C. RAO, B.Sc, B.E. (Hons), Jun. ASCE, A.M.I.E. (India)

Executive Engineer, Hirakud Dam Project

The foundations at the Hirakud Dam consisted of hard and massive rock with numerous faults and fissures and crushed zones. Therefore it has been a strenuous work to prepare it for the construction of the Dam. The method of treatment consisted of preliminary low pressure consolidation grouting followed by a deep grouted cut off and drainage arrangements. How these were achieved and the experience gained therefrom is described by the author in this contribution.

AUTHOR

High pressure grouting is applied to deep holes called "A" holes drilled near the upstream face of dam to form the principle grout curtain or seepage barrier. Holes are generally spaced at 20 ft. centres. In order to permit the application of high pressure without the movement of foundation surface layers or loss of grout through surface cracks this grouting procedure is carried out subsequent to low pressure grouting operations and after some of the structural concrete or masonry has been placed. This is accomplished from galleries within the body of the dam and sill of sluices or from the heel of the dam where no gallery is provided.

Foundation drainage is provided by a series of holes 3″ in diameter, drilled into the foundation rock at about 15 ft. centres through 4″ diameter pipes which extend for 3 ft. depth below the floor of the gallery. These are located on a line 21′-3″ down stream and parallel to the axis of dam.

Introduction

This paper deals with the drilling and grouting of high pressure curtain grout holes as well as the drilling of foundation drainage holes in Left Concrete Dam and Right Spillway and Power Dam during the period November 1954 to August, 1956.

The Left Concrete Dam consists of a spillway 1200 ft. long (Blocks 3 to 23) flanked on either side by masonry nonoverflow sections 144.5′ and 274.5′ respectively. The maximum height in this section is 152ft. The Right Spillway and Power Dam consists of a concrete spillway section and masonry Power Dam transition sections upto the right abutment having a total of 2150 ft. The maximum height in this section is 200 ft.

Geology of Foundations

The bed of the river was rocky and the rocks of the region were composed mostly of granitic gneiss, schist, slates and shales intersected by numerous joints, seams, fissures and shear zones. The blocks on the extreme right abutment consisted mostly of shales, arkoses and quartzites. To reduce seepage losses through the foundations and uplift pressures under the dam, extensive grouting of the foundations of the concrete and masonry sections of the dam was carried out.

Sri Rao is now with the Nagarjun Sagar Dam Project.

General Method of Treatment

The method of treatment of the foundation of concrete section consisted of low pressure shallow grouting for consolidation and improving the stability of the upper portions of the foundation rocks followed by a high pressure deep grouting intended to create a tight curtain which will cut off any path of percolation along the base of the dam and through the foundation rock to the depth of the grout holes. In order to intercept any seepage between the dam and bed rock or through the grout curtain, deep drainage holes were drilled along the downstream side of the curtain.

The consolidation grouting work was started in the year 1951 and completed by 1954. The high pressure grouting was started in the latter part of 1954, and completed by June, 1956. This paper deals with the high pressure grouting and drainage arrangements done during this period.

Size and Depth of Holes

The high pressure curtain grout holes were drilled 60′ deep below the foundation rock level, and at 20′ intervals generally along a line parallel to the axis of dam and located at 17′-6″ downstream of axis of dam. The spacing was reduced to 10 ft. 5 in. and 2½ ft. in certain sections where fault zones were met with. The drainage holes were drilled 50′ deep along a plane just downstream of the grout curtain. The size of grout holes varied from 2½″ to 1½″. The drainage holes were 3½″ to 3″ diameter. All the holes were drilled with the diamond core drills. The depth of concrete cover varied from 3 ft. to 23 ft.

Pattern of Holes. ("A" Holes and "D" Holes).

"A" Grout holes.

The drilling and grouting of the curtain and drainage holes was effected from the floor of the drainage gallery located at about R.L. 497 in the Right Spillway and Power Dam and at R.L. 500 in the transition section of Left Concrete Dam through previously embedded pipes. The curtain holes were located near the upstream edge of gallery on a line 17′-6″ down stream of axis and drainage holes near the downstream edge of gallery along a line 21′-3″ down stream of axis.

In the blocks 3 to 23 of left concrete dam, where no gallery was provided, the treatment was effected from the sill of the river sluices at R.L. 509 through previously embedded pipes. The curtain holes were locat-

ed on a line about 8 ft. downstream of axis with the top of holes at R.L. 509. The drainage holes were located on a line about 11′ downstream of axis with the top of holes at R.L. 509.33.

In the Left Concrete Spillway section, satisfactory hard rock foundation was met with at fairly high level and there was not sufficient excavation below the sill of sluices to permit the provision of a drainage gallery of the standard size. Hence a 3 ft. diameter header was provided in this section with connection to the drainage sumps in the gallery at either end of this section as shown in figure 2. Provision was made for getting access to this header at three places along its length through man-hole openings in this sill of slucies in blocks 9 & 16. These openings were kept closed by suitable man-hole covers and the surface kept flush with the sill of sluices. The length of header is 1260 ft.

The grout holes were first drilled at 40′ centres and grouted, after which the secondary holes were drilled and grouted at 20′ centres. In certain blocks where grout consumption has been excessive or where foundation conditions warranted, additional intermediate holes were drilled at 10′ and 5′ centres respectively and grouted. In the gallery at R.L. 470 in blocks 53 & 54 where large water flows were noticed from drilled holes additional holes have been drilled and grouted as close as 2½ ft. centre to centre.

Progress of Work

Curtain grouting and drainage hole drilling were started first in Left Spillway in November, 1954. Drilling of drainage holes was started after the curtain grouting has been completed in at least 4 consecutive blocks. Total of 6058 ft. have been drilled and grouted and 3768 ft. of drainage holes have been drilled and capped. After the completion of drilling, the drainage holes were plugged for the portion of the hole between the sill of sluice and the top of the header. The method of filling was as follows: A 2″ I.D pipe of about 3 ft. length with the bottom sealed and jute tied round its lower end was inserted into the hole, so that the bottom of the pipe was at a level corresponding to the top of the header, the top of the pipe being 6″ below the sill level. Then grout and mortar was poured and packed in the annular space between the pipe and the hole as well as inside the pipe, the top of the hole finished in mortar flush with the sill of sluice and polished with carborundum stone.

The entire work on Left Concrete Dam was completed by August, 1955.

After the completion of the work on the Left Concrete Dam, all the equipment were moved to Right Spillway and Power Dam section. The drainage gallery was thoroughly cleaned and washed, including the sumps, and lighted for the entire length. Suitable size of drainage pumps were installed on the platforms in the pump wells in blocks 34 and 47. Drilling of high pressure grout holes was started about the middle of December, 1955 and washing and grouting operations were started in January, 1956. Work was carried on continuously in 2 shifts, with 4 Pneumatic Diamond Drills and 2 Gardner Denver Grout Pumps. The curtain grouting was completed by end of August 1956 and drilling of drainage holes is in progress now which will be completed by November 1956.

Pressures used

The maximum pressures used on the curtain holes with settings of expander packer is as follows :

Location of packer	*Pressure*
40′ in rock.	200 P.S.I.
20′ ,,	170
2′ below rock level.	150
2′ below gallery drainage (in concrete)	30

Drilling and Grouting Procedures

At the time of construction of the foundation gallery, 3″ G-I. pipes, 3 ft. long were embedded in the concrete floor of the gallery with the top of pipes in level with the bottom of the drain in the gallery. All these pipes were kept closed by plugs during construction. The pipes were provided at 20′ spacing in general with proper direction and angle, and with reduced spacing in certain blocks where foundation condition warranted the provison of curtain grout holes at closer intervals. 4″ pipe nipples provided with a Tee and a cross pipe were embedded at 15′ intervals along the downstream edge of the gallery for drilling drainage holes. In the Left Spillway (block 3 to 23) where no gallery was provided, pipes were embedded in the sill of sluices while concreting the sill.

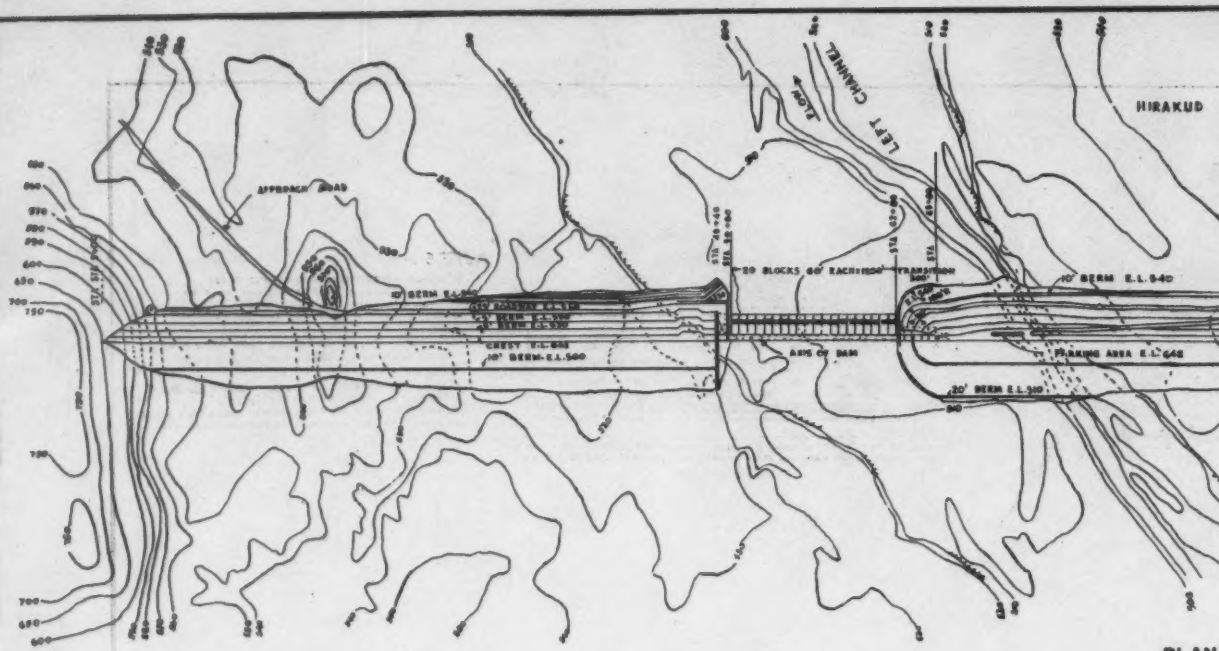
After the Dam has come up to about R.L. 620, i.e. about 120 ft. above foundation level, drilling and grouting operations were started. (Top of Dam is at R.L. 642). The holes at 40′ centres were drilled and grouted, first, the depth of holes being 60 ft. below foundation rock level. Then the holes were inclined at about 65 ft. During drilling, careful observation were made regarding loss of drill water, and seepage flows in the hole.

With the exception of the holes in blocks 54, 59 and 60 near the right abutment, all the holes were drilled in one stage to the full depth using diamond core drills. When the drilling of a hole was completed, it was capped to prevent debris from entering the holes. These were washed to the full depth using a blow pipe with air and water in order to throughly clean the hole of all drill cuttings etc., till the wash water became clear This took about 20 minutes. Washing of seams between the drilled holes was then attempted with the packer placed at 30′ below the foundation level in alternate holes and allowing air and water under pressure. This was continued for nearly 4 hours. If there were no interconnection between the holes, the holes were taken up for grouting after pressure testing with water.

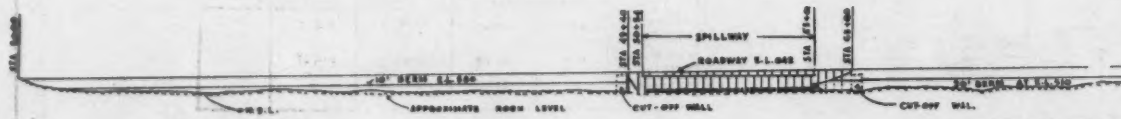
Where interconnections between holes were noticed washing operations were continued till the material in the seams was completely washed out and effluent from the interconnected holes was fairly clear after which grouting was started. Galvanised iron sheets were used around each drill rig to protect the walls from oil, grease and other stains.

Before starting the grouting of any hole, the hole was tested by pumping water at the maximum allowable pressure for about half an hour with the packer set at the desired depth noting the rate of flow from the readings taken in the agitator tank. The amount of water taken by the hole gave sufficient data for

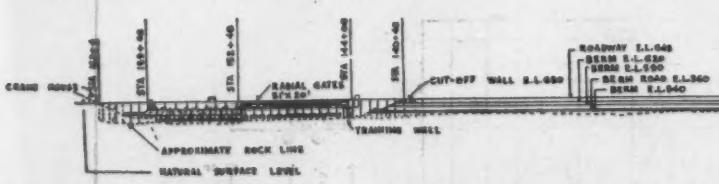
Vintage



PLAN

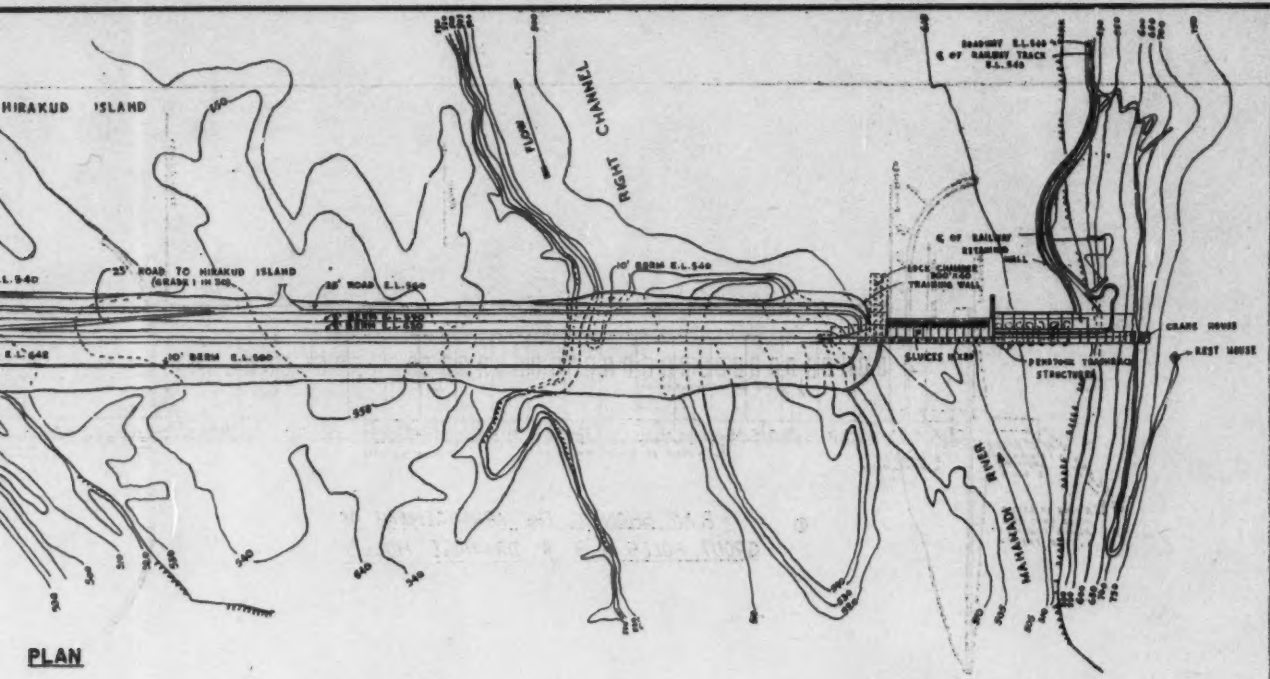


UPSTREAM E



DOWNSTREAM

FIG 2



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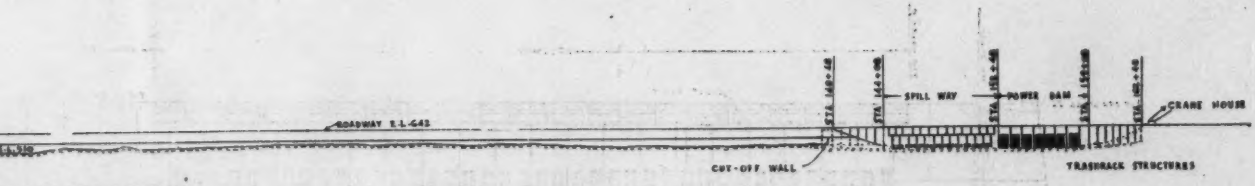
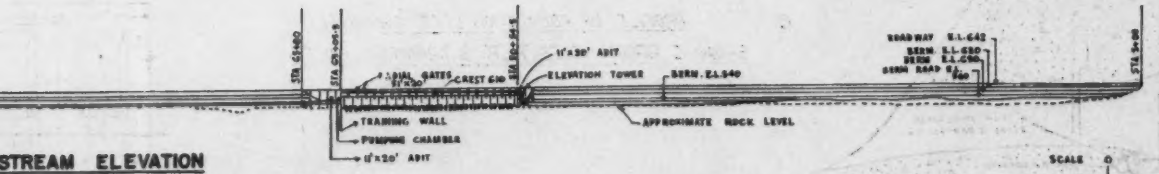


REAM ELEVATION



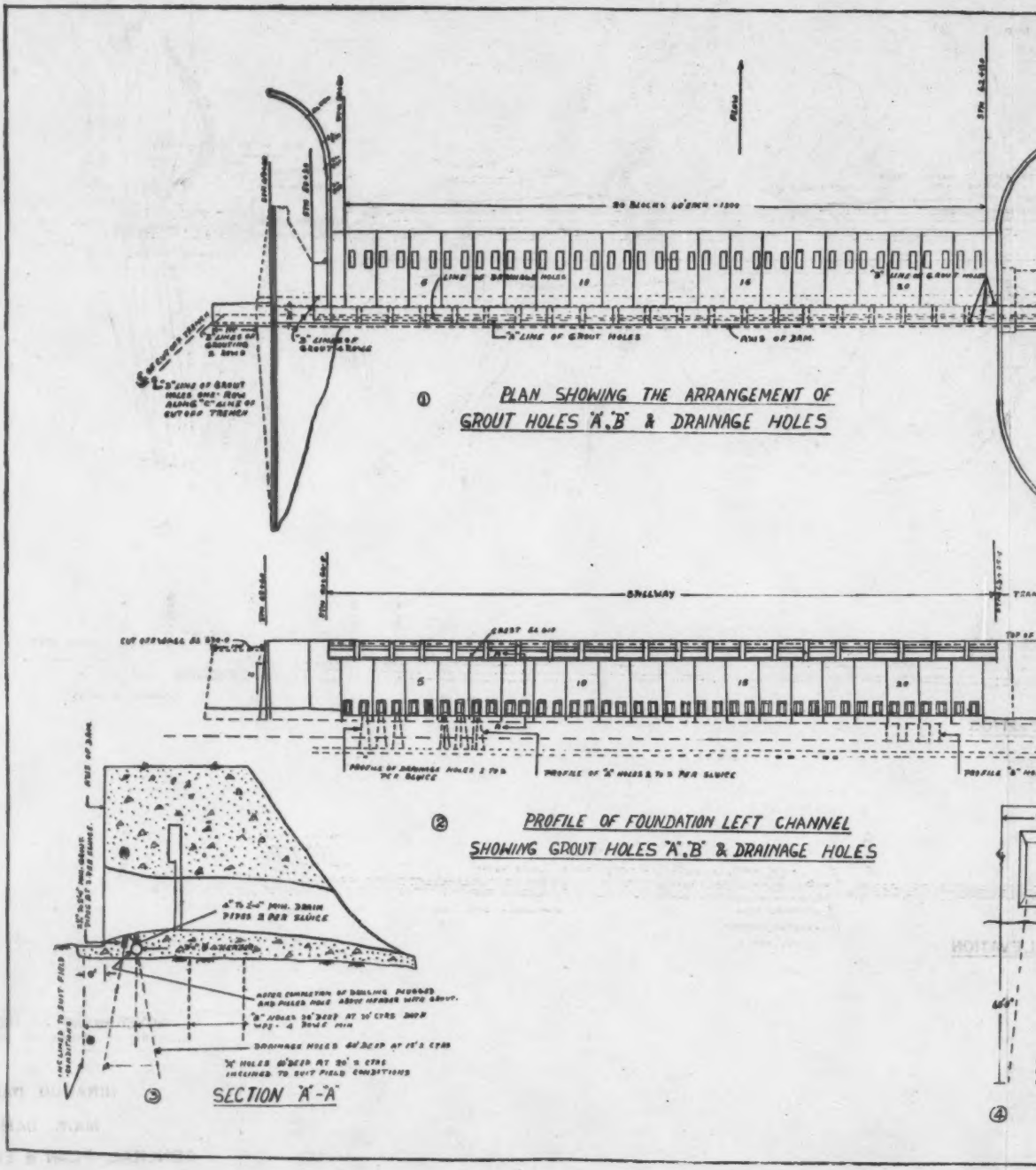
STREAM ELEVATION

SCALE 0 500 1000 1500 FEET

GOVERNMENT OF INDIA
MINISTRY OF IRRIGATION AND POWER

HIRAKUD DAM
MAIN DAM
GENERAL PLAN & ELEVATION

AUGUST, 1954.

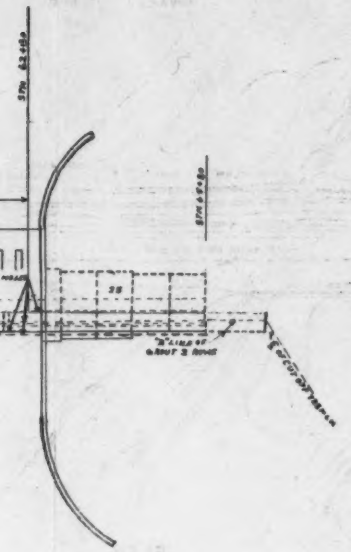

20 BAYS 60'EACH =1200
"A" LINE OF GRAUT HOLES
"B" LINE OF GROUT HOLES
"C" LINE OF GROUTING & DRAINS
"D" LINE OF GROUT HOLES ONE ROW ALONG "C" LINE OF CUT OFF TRENCH
SPILLWAY
PROFILE OF DRAINAGE HOLES 2 TYP. PER SLUICE
PROFILE OF "A" HOLES 2 TO 5 PER SLUICE
6" TO 8" DIA. DRAIN PIPES 2 PER SLUICE
NOTE: COMPLETION OF DRILLING PLUGGED AND PILLED HOLE ABOVE MEMBER WITH GROUT.
"B" HOLES 20' DEEP AT 20' CTRS. SHOT WITH 4 BAGS PER HOLE
DRAINAGE HOLES 40' DEEP AT 15' CTRS
"A" HOLES 60' DEEP AT 20' CTRS INCLINED TO SUIT FIELD CONDITIONS
INCLINED TO SUIT FIELD CONDITIONS

① PLAN SHOWING THE ARRANGEMENT OF GROUT HOLES 'A','B' & DRAINAGE HOLES

② PROFILE OF FOUNDATION LEFT CHANNEL SHOWING GROUT HOLES 'A','B' & DRAINAGE HOLES

③ SECTION 'A'-'A'

④



SYMBOL	HOLE	DIA.	DEPTH	SPACING	REMARKS
○	"A"	1¾"	60'	20	DRILLED & GROUTED UNDER HIGH PRESSURE
⊙	"B"	1¾"	30'	20	DRILLED WASHED AND GROUTED UNDER LOW PRESSURE
⊙	DRAINAGE HOLES	5"	50'	15	DRILLED DRAINAGE HOLES AFTER MEETING SPECIFIED GROUTING REQUIREMENTS.
	AFTER GROUTING OPERATIONS WERE COMPLETED 2¾" Ø PIPES FOR "A" HOLES WERE BROKE OFF FLUSH WITH THE FACE OF CONCRETE IF PROTRUTING ABOVE.				

SPACING OF THE "A" HOLES WHEN GROUTING FROM UNDER SLUICES WAS 2 TO 3 FOR UNDER SLUICE, WHEN GROUTING FROM FOUNDATION GALLERY WAS 20 & 10 C

NOTES :-

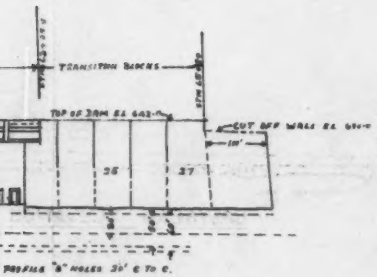
"B" HOLES WERE DRILLED AND GROUTED AFTER COMPLETION OF THE EXCAVATION AND PRIOR TO PLACING CONCRETE.

"A" HOLES WERE DRILLED AND GROUTED THRU PIPE EMBEDED IN CONCRETE.

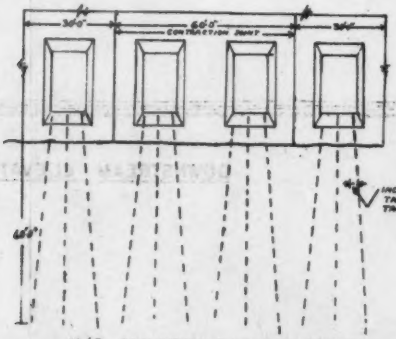
DRAINAGE HOLES WERE DRILLED THRU PIPES EMBEDED IN CONCRETE AFTER COMPLETION OF "A" HOLES GROUTING.

MINIMUM DIAMETER OF GROUT & DRAINAGE HOLES WERE 1¾ AND 5" RESPECTIVELY.

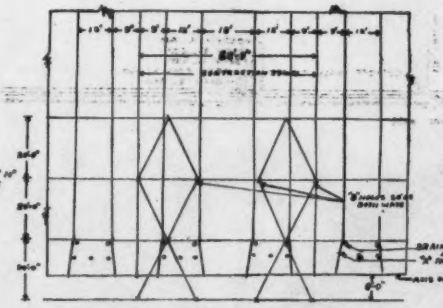
FINAL LOCATION OF FOUNDATION GALLERIES WERE DETERMINED BY ACTUAL FOUNDATION EXCAVATION.



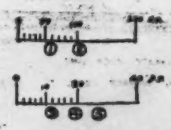
	TYPE OF WORK.	NO. OF HOLES DRILLED CASING	TOTAL FOOTAGE DRILLED & CASING	TOTAL NO. OF BAGS OF CEMENT PLACED	AVERAGE TAKE PER LINEAL FOOT	REMARKS
1	CONSOLIDATION - GROUTING	552	13032	5936·6	0·457	
2	HIGH PRESSURE GROUTING	113	6958	2464	0·407	
3	DRAINAGE	61	3073	—	—	



④ U/S ELEVATION SHOWING GROUT SCHEME FOR "A" HOLES



⑤ PLAN SHOWING ARRANGEMENT OF GROUT HOLES A-B & DRAINAGE HOLES



HIRAKUD DAM PROJECT

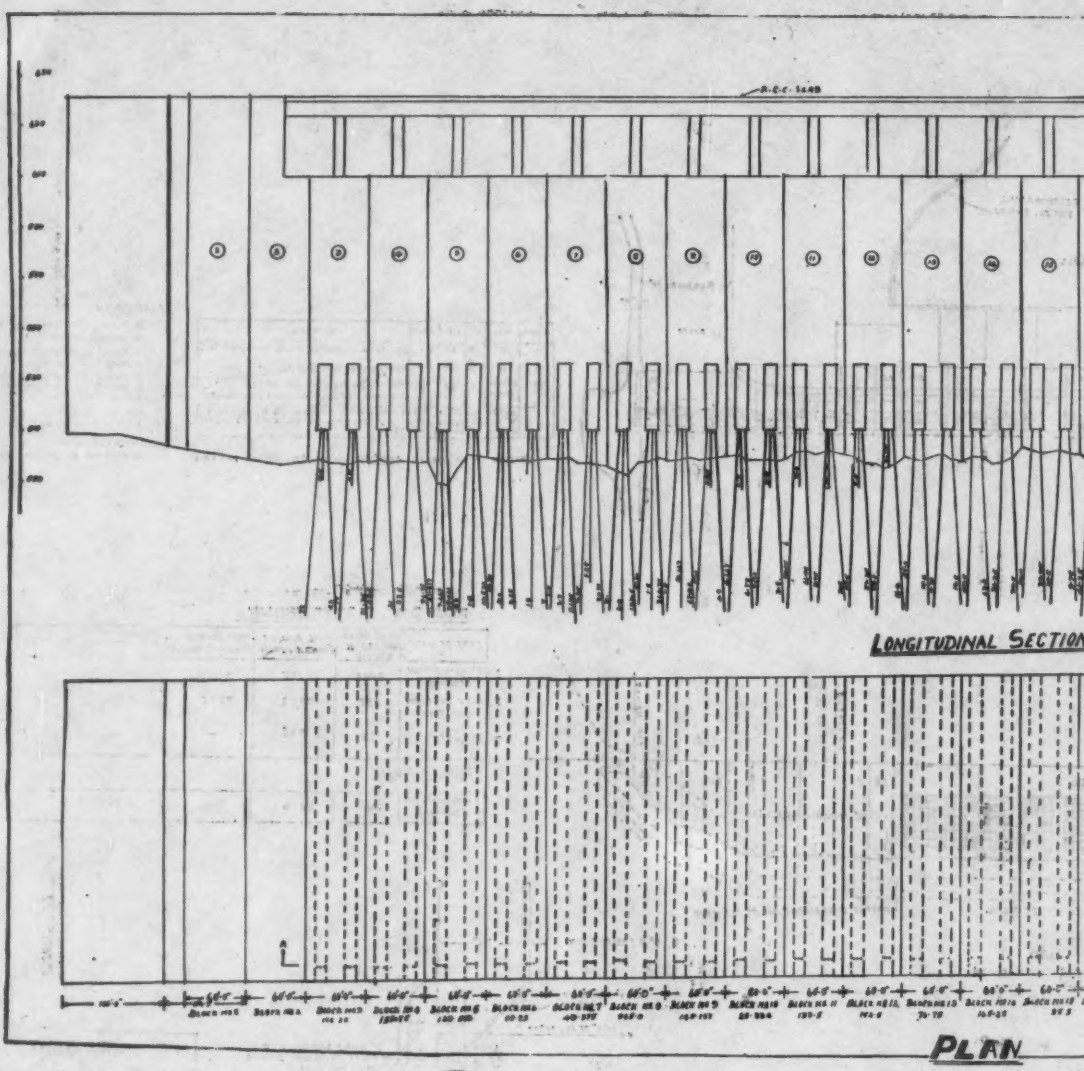
LEFT CONCRETE DAM.

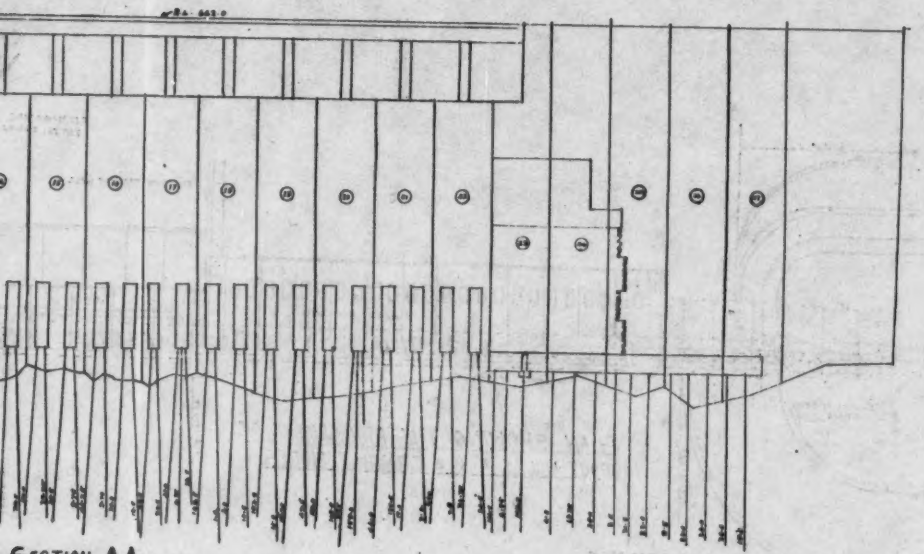
FOUNDATION GROUTING AND DRAINAGE

EXECUTIVE ENGINEER

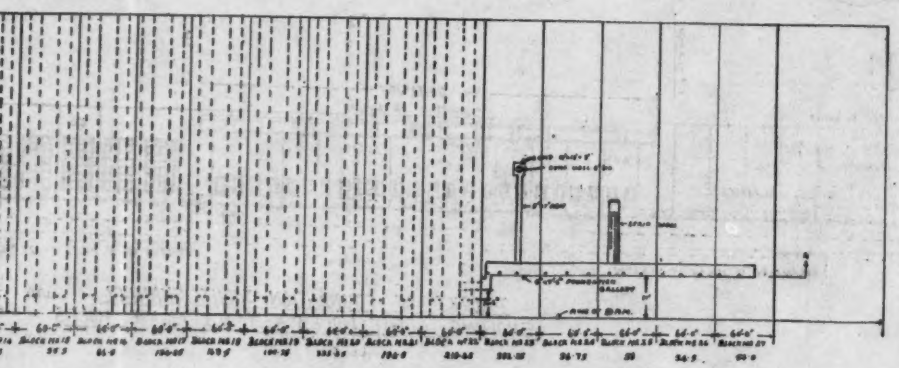
FIG. NO. 2.

Ficang Page 64





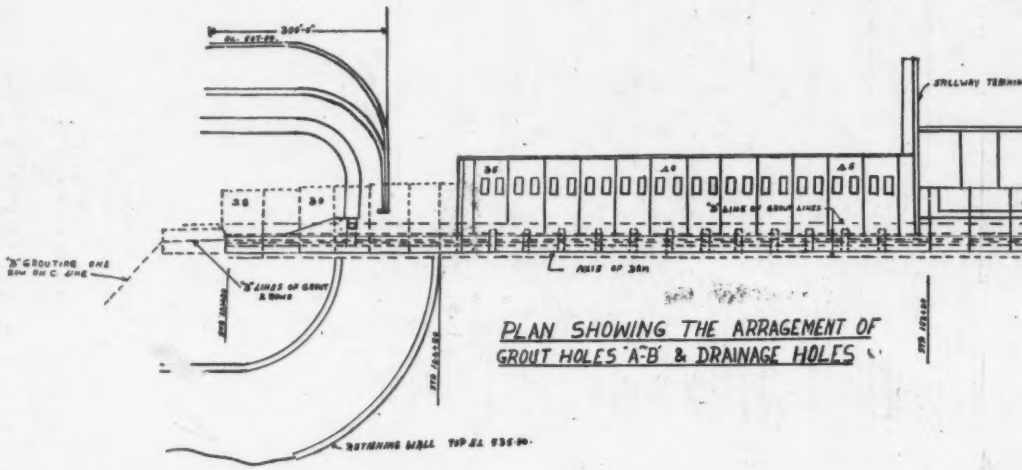
SECTION AA

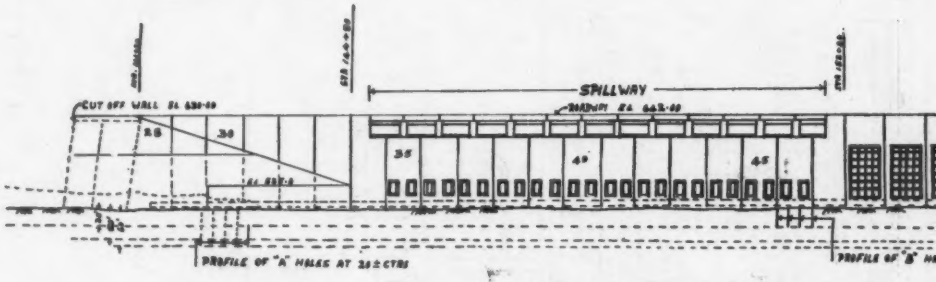


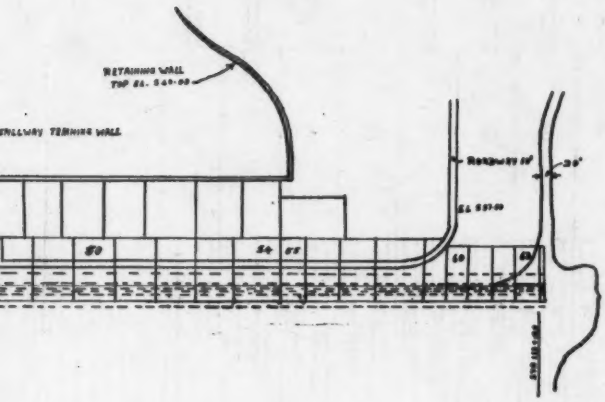
BLOCK NO.	TOTAL NO. OF HOLES DRILLED & GROUTED	TOTAL FOOTAGE DRILLED & GROUTED IN ROCK.	TOTAL BAGS OF CEMENT PLACED IN ROCK.	AVERAGE TONS PER LINEAR FOOT.
3	6	257'-0"	60	0-233
4	4	248'-0"	490	0-396
5	6	243'-0"	38-00	0-157
6	6	206'-0½"	12-5	0-060
7	6	246'-0"	30-375	0-123
8	8	243'-0"	237-50	1-000
9	6	209'-6"	42-5	0-201
10	6	246'-3"	16-75	0-068
11	6	267'-3"	67-5	0-253
12	7	279'-8"	19-25	0-069
13	4	241'-1"	30-75	0-128
14	4	248'-0	107-5	0-433
15	4	249'-8"	35-75	0-143
16	4	241'-6"	40-0	0-166
17	5	278'-7"	65-5	0-235
18	4	230'-6"	140-0	0-608
19	4	248'-0"	107-0	0-430
20	5	256'-3"	230-0	0-898
21	4	241'-10"	124-0	0-515
22	4	248'-0"	185-75	0-750
23	3	193'-0"	330-0	1-708
24	3	180'-10"	58-0	0-321
25	3	186'-0"	31-5	0-170
26	3	180'-2"	23-5	0-128
27	2	120'-8"	18-0	0-149
TOTAL	117	4238'-9½"	2441-25	0-576

HIRAKUD DAM PROJECT
LEFT CONCRETE DAM
HIGH PRESSURE GROUTING

DRAWN :-	G. Ghosh EXECUTIVE ENGINEER
TRACED :-	
CHECKED :-	
SCALE :- 1"=30'-0"	DRG. NO 17/ FIG. NO 3


"A" GROUTING ONE
ROW ON C LINE
"B" LINES OF GROUT
B ZONE
AXIS OF DAM
RETAINING WALL TOP EL 936.00
PLAN SHOWING THE ARRAGEMENT OF
GROUT HOLES "A-B" & DRAINAGE HOLES


SPILLWAY
CUT OFF WALL EL 630.00
PROFILE OF "A" HOLES AT 20± CTRS
PROFILE OF FOUNDATION RIGHT CHANNEL
SHOWING GROUT HOLES "A-B" & DRAINAGE HO



SYMBOL	HOLE	DIA	DEPTH	SPACING	REMARKS
○	"A"	1⅞"	60'	20	DRILLED AND GROUTED UNDER HIGH PRESSURE
×	"B"	1⅞"	30'	20	DRILLED WASHED AND GROUTED UNDER LOW PRESSURE.
⊙	DRAINAGE HOLES	3"	60'	15	DRILLED DRAINAGE HOLES AFTER GROUTING SPECIFIED GROUTING REQUIREMENTS
					AFTER GROUTING OPERATIONS WERE COMPLETED 3½" Ø PIPES FOR "A" HOLES WERE BURNT OFF FLUSH WITH THE FACE OF CONCRETE IN PRODUCTION HOUSE

SPACING OF "A" HOLES FROM FOUNDATION GALLERY WAS 20 ± CTRS

NOTES :-

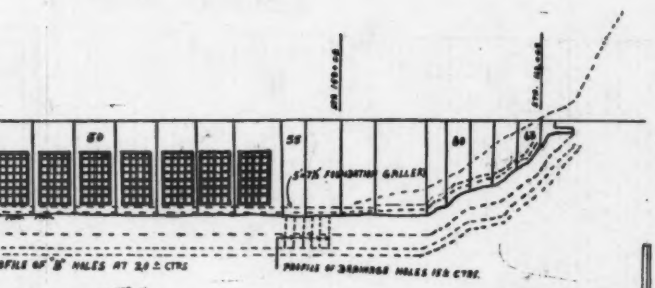
"B" HOLES WERE DRILLED AND GROUTED AFTER COMPLETION OF THE EXCAVATION AND PRIOR TO PLACING CONCRETE.

"A" HOLES WERE DRILLED AND GROUTED THRU PIPES EMBEDDED IN CONCRETE AFTER COMPLETION OF "B" HOLES GROUTING.

DRAINAGE HOLES WERE DRILLED THRU PIPES EMBEDDED IN CONCRETE AFTER COMPLETION OF "A" HOLES GROUTING.

MINIMUM DIAMETER OF GROUT AND DRAINAGE HOLES WERE 1⅜" AND 3" RESPECTIVELY.

FINAL LOCATION OF FOUNDATION GALLERIES WERE DETERMINED BY ACTUAL FOUNDATION EXCAVATION.



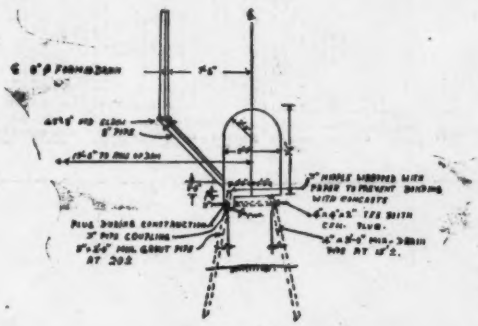
HANNEL
NAGE HOLES

POWER DAM & RIGHT SPILLWAY

	TYPE OF WORK	NO OF HOLES DRILLED & GROUTED	TOTAL FOOTAGE DRILLED & GROUTED	TOTAL NO OF BAGS OF CEMENT PLACED	AVERAGE TAKEN PER LINEAR FOOT	REMARKS
1.	CONSOLIDATION GROUTING	2034	55735	9747·87	0·176.	
2.	HIGH PRESSURE GROUTING	131	7812	2378	0·30.	
3.	DRAINAGE	16	960	—	—	

POWER HOUSE

CONSOLIDATION GROUTING	134	2878	894	0·31	


℄
6" Ø FORMED DRAIN
45°-6" STD ELBOW
6" PIPE
12'-6" TO FLOW LINE
3" HOLE WELDED WITH PLUG TO PREVENT SEEPING WITH CONCRETE
PLUG DURING CONSTRUCTION
3" PIPE COUPLING
6'-6" TEE WITH CON. TWD.
6"x6" HOR. GROUT PIPE AT 20'
6"x3'-0" HOR. DRAIN PIPE AT 15'-0"

FOUNDATION GALLERY

SCALE :-
VER 1" = 100'
HOR 1" = 100'

HIRAKUD DAM PROJECT

RIGHT CONCRETE DAM-
FOUNDATION GROUTING & DRAINAGE

EXECUTIVE ENGINEER

FIG NO 4.

deciding the initial grout mix to be used, the initial pumping pressure to be used and the most efficient rate of injection.

After each hole has been water tested, grouting was started, using neat cement grout with the $\frac{W}{c}$ ratio depending on the results of the water test. Rubber packers were used in grouting. Grouting was started from the bottom of the hole and carried progressively upward to the top of the hole. Before a hole was taken up for grouting, it was made sure that all the holes for about 80′ on either side of it have been thoroughly washed and water tested. Otherwise, if grout leaks into a hole that has not been washed, the grouting operation gets interrupted and continuity is lost, because the interconnected holes have to be washed before resuming the grouting. If grout leaked through the adjacent holes, these were capped with plugs to prevent wastage of grout. Grouting was continued at the pressure varying from 100 to 250 PSI, and continued until the hole took grout at the rate of less than 1 cft. of grout mixture in 10 minutes.

Once the grouting of a zone in a hole is completed, the grout header was removed after about 15 minutes and the packer was raised and fixed at a higher level and the upper zones grouted. This procedure was continued till all the zones were grouted up to the top of the hole. Where the hole has got interconnected holes they should be washed to the full depth and taken up for grouting one after the other. The bottom zones of all these interconnected holes should be grouted before attempting to grout the upper zones of the first hole.

Grout Mixes

Grout mixes varied from 15 :1 to 0.5 : 1 by volume. Grout initially injected was a thin mix varying from 12 : 1 to 10: 1 so that we can get the "feel" of the hole without danger of losing it. If the hole accepted grout at a fairly high rate, the $\frac{W}{c}$ ratio was gradually reduced until the hole was accepting the maximum number of bags of cement per hour, at the maximum allowable pumping pressure. However, if the rate of injection slowed down with the thicker mix under the maximum allowable pressure, the hole may be plugging. The grouting is then stopped, and the hole washed under water pressure to open it again and grouting resumed with a thinner mix until the hole refused grout at the maximum allowable pressure. If the injected grout is too thick, seam passages may become obstructed at a short distance from the hole and fine seams will not be filled. If the grout is too thin, voids will form in the fissures after the grout sets and shrinks. The optimum $\frac{W}{c}$ ratio should be carefully selected and modified during the progress of grouting so that the grout will contain enough water to compensate for absorption losses in the rock and to remain sufficiently fluid to fill all voids, fissures and seams.

Equipment used

All the grout holes and drainage holes were drilled with diamond core drills. They were of different makes and types as shown at the end of (Table I). Petrol engin and diesel engine heavy duty drills were used for drilling the grout holes and drainage holes from the sill of river sluices (of size 12′ × 20′-3″) on the Left Spillway blocks and pneumatic drills CP-55 A, were used for drilling inside drainage gallery of size 5′×7½′ located in the body of the dam. The petrol driven drills could not be used inside the gallery because the space is restricted and because the exhaust from the engine produces carbon monoxide which is poisonous. Also working area gets heated up and causes much discomfort to the workmen inside.

Petrol Engine Heavy Duty Drills

The petrol engine drill consisted of the following parts.

(1) *The Clutch Lever*:

This is used for stopping the drill without stopping the engine. Whenever drilling is to be stopped for short periods the drill is disconnected from the engine or motor by means of this. When drilling has to be stopped, for fairly long time the engine also is stopped.

(2) *Speed Shifts* :

When speed is changed the clutch is first released. It is then re-engaged very slighlty to enable the drill bit to rotate slowly, and the handle is moved to the desired position.

(3) *Drum Gear Shift Handle* :

This handle controls the movement of the hoisting drum or the level gear as the case may be. When the power has to be transmitted to the level gear for drilling, the handle is moved towards the motor. When the rods have to be hoisted or lowered by the drum, this handle is moved away from the machine. In this position, only the hoisting drum rotates and not the drillings level gear.

(4) *Cathead* :

This is put into operation by moving its jaw clutch whenever required.

(5) *Hoisting Drums* :

This is used for hoisting the rods, lowering the rods, moving the drill under its own power and for driving the casing.

(6) *Swivel Head* :

Swivel head is that part of the drill which directly governs the rod and bit rotation and rate of bit advance. Both screw feed and hydraulic feed types were used. There are 3 sets of selective feed gear providing three optional feed rate of advance of the bit while the drill is in operation.

Pressure Gauge :

The gauge indicates the pressure on the bit in lbs/sqin.

Safety Chuck :

There are chuck jaws inside the clutch. These jaws are tightened by clutch both for gripping the drill rod of proper size firmly and transmit the rotation of the drill spindle to the bit.

Pneumatic Drills

The Pneumatic drills were of the CP 55 A model manufactured by M/S Chicago Pneumtic Tool Co. This is a light weight, compact, screw feed machine

designed to be mounted like a drifter on a column and is powered by a six vane rotary air motor. Overall length is 42½".

Air consumption at full load is about 250 cft. at 80 lbs. pressure per sq in and at average load it is about 170-180cfm. One Broomwade Compressor of 250 cfm capacity was able to run 2 drills without any difficulty.

The motor consists of a rotor mounted eccentrically in a cylinder. Around the motor there are 6 slots in which blades or vanes move in and out as the motor revolves. These blades and the motor are the only rotating parts. Ball bearing motor, housing liner, end plates and blades are the only wearing parts.

A built-in screw feed swivel head with four sets of feed gears is used. Any gear can be thrown into action without stopping the drill. Ball bearings take the thrust of the drilling and the weight of the drill rod. The length of feed is 21" and the bit rotation speed is from 0 to 1500 RPM. (Optional speeds from 0 to 2000 and 0 to 2500).

The chuck is a safety type chuck with oversize countersunk set screws holding the chuck jaws, thereby eliminating the possibility of catching the operators clothing. It is machined all over to get perfect balance. With "E" rod and EX core barrel this machine has a capacity of 500 ft.

Gear Changes

There are four feed gears on the drill 200, 300, 400 and 500 revolutions per inch of bit advance. This wide range of feeds makes it unnecessary to carry any spare gears with drill. The feeds are progressive, with first gear towards the front of the drill, slow feeds at rear. Gears are engaged by turning the shifter handle until larger part of the handle is midway between the Lower "N" stamped on housing or as far as it will go in either direction. For fast feed it should be turned counterclockwise. There are 3 neutral positions, marked by letter "N" on housing one being between each feed. At the end of the run when the feed screw is to be raised, the shifter handle is moved to neutral position and the feed nut stop pin is pressed and throttle is opened slowly when the feed screw rises. When the chuck is about an inch from the housing, the top pin should bereleased and throttle should be closed. To re-engage the gear, the shifter handle should be moved towards the gear to be used and throttle should be opened slightly, when feed gear will slip into position.

This machine is provided with a rod puller which is generally used when pulling the drill rods from holes over 100 ft in depth. This has got a 4½" diameter piston and 21" travel. The rod puller lifts the rods very fast and thereby gives more time for drilling. Up to 100' the rods can be pulled by hand using wrenches. The feed screw easily accommodates EX Core barrel obviating the use of short core barrel for starting holes.

Moving and setting up of Drill

(*a*) In the case of heavy duty drills used on the Left Spillway, the drills were first moved opposite to the sluice opening. It was lifted by a crane and put at the location of the hole on a timber platform set on the concrete sill of the sluice and levelled up. The machine

Photo 1—Craelius petrol engine driven diamond drill, drilling drainage holes from the sill of river sluices—Left Spillway section.

was anchosed down down by loading the drill frame with bolders as shown in Photo 1. Where found neccessary additional anchorage was provided by putting turnbuckles attached to 1" rods anchored into the sill or the sides of the sluice. Water line was connected to the water swivel by means of a hose.

Drilling was first started with a 2 ft. starting barrel after the completion of which, regular 5 ft. core barrel was used.

The core barrel was fitted up with reaming shell, core lifters and bit and is lowered into the hole and connected to the drill rods. The chuck bolts holding the drill rod was tightened. When the clutch was thrown in, the drill rod and chuck rotated but there was no downward motion. To start the downward motion the angle valve is closed and the handle of 4-way valve is opened. The hydraulic fluid, either water or oil, under pressure moved to the top of the hydraulic cylinder and pushed the piston down. The speed of the downward motion was controlled by the escape of the fluid, through the needle valve into the sump.

When the pistons have reached the bottom of the stroke, and another run has to be made, the rods are stopped from rotating by throwing out the clutch. The 4-way valve is returned to its horizontal position, the needle valve is closed and the angle valve is opened. The clutch bolts are loosened and the 4 way valve handle is moved up, allowing water or oil to enter the bottom of the cylinder and push the piston up. The valve is then returned to its horizontal position up and the chuck bolts are tightened. Another drilling "run" can be started now.

After a run of 5 ft., drilling is stopped and the hydraulic swivel head was swing out of the line and the core barrel was pulled out of the hole and the bit along with the reaming shell and the core lifter is removed. Before the drilling was stopped drill water was allowed to flow through the core barrel assembly till the waste water became clear. This enabled all the cuttings to come out, thereby making further drilling easier.

The core was then placed in a tray and then trans-

ferred to its correct place in the core barrel. The depth of the run and the core loss in the run was marked on the distance piece. The bit, shell and barrel are washed well and then assembled again and lowered into the hole. Extension drill rod was provided to the string of drill rods. Drilling was started again after all the drill rods were put in through the hydraulic, the hydraulic was swung back into position and the drilling rod was screwed into the line of rods already in the hole and tightened up. The water swivel was attached and flush water was let in through the rods after which drilling was re-started.

(*b*) In the case of the Pneumatic drill inside the gallery, moving and setting up of diamond drill was very much simplified, as the machine was very light. At the time of constructing the gallery 3″ pipes 2′ long were embedded in the concrete floor of the gallery at intervals of 20′ along the line of grout curtain, as shown in drawing 3. The vertical column with screw was set up on a timber base and it was clamped to the 3″ casing pipe. At the locations where no casing pipe was embedded, the drill was set up on the gallery with timber supports as shown in photo 2.

Photo 2—Cp 55 A, pneumatic diamond drill drilling high pressure grout holes inside the foundation gallery at R. L. 470 Power Dams Section.

Water line was connected to the water swivel. Air hose about 10′ long was connected to the motor. The motor was lubricated by a line oiler which along with a short air inlet hose was supplied as standard equipment with each machine. The oiler was always kept horizontal. SAE 10 or 20 oil was used in the oiler depending on temperature. Care was taken to see that the air hose was blown out clear before attaching it to the inlet.

B. Grouting Equipment

There area number of grout pumps now being manufactured. It is difficult to use a pump as it is received from the factory and obtain satisfactory cement grout service with it without first making some vital modifications.

The grouting plant used at Hirakud consists of a 4″×6″ Gardner Denver, Duplex double acting reciprocating pump fitted with Caterpillar Diesel Engine Model D 3400, a mixing drum of 20 cft. capacity and an agitator tank of 18 cft. capacity mounted on skids as shown on drawing fig. 4. The mixer and agitator were manufactured in local workshops and they were operated by manual labour.

Working Data:

The engine has a horse power of 30.
Pump Model: FG—FxG—G –suction 4″
Maximum speed: 65 RPM Delivery 2″
Maximum working pressure of pump 900 psi
Size of piston 4″
Stroke 6″

The pump was originally received here as a water pump. It was converted into a grout pump by making some modifications like providing liner sleeves made of special steel, providing rubber pistons, changing the valves, valve seats and springs.

The pump is run by a Caterpillar diesel engine of 30 H.P. mounted on the same skid. The drive is transmitted to the pump through drive belts. The pump is of the side-pot-type. Each valve is located in a separate pot or chamber. Each valve pot has an independent cover which has to be removed before the valve can be reached. The advantage of this type is that all the valves and seats are interchangable. Also each valve has a separate cover plate which permits the suction valves to be removed and cleaned without disturbing the exhaust valves as in the case of a line type pump.

Operation of the grout pump

A grout pump should always be given close attention. When pumping into a hole that takes some hours to fill, grout settles within the valve chambers and parts and may foul the valves or partially plug some of the passages. As it required some time to clear the pump thoroughly it is better to prevent the deposition of grout. The deposition of grout can be reduced by closing the valve to the supply line and opening the bypass grout can then be circulated through the pump at a high velocity, for a few seconds. This will scour out a lot of thick grout and return it to the agitator. When pumping grout continuously for several hours, grout is likely to settle in the pipe lines also. In such cases, water should be pumped and circulated for about 5 minutes at intervals of every 4 hours in order to keep the pump and pipe lines clear of hardened grout. Some water can be let into the hole also through the packer so as to keep all the passages open. At the end of each day's work, the pump should be opened out, all the hardened and deposited grout should be removed from all the chambers and the pump thoroughly cleaned and washed and closed again.

Accessories for pump

Cement grout is highly abrasive even at low pressure The parts of the pump are easily ruined in a short time. Hence special types of parts are used so that costly delays could be avoided.

Valves :

The valves of the grout end of the pump consisted of a rubber seal fastened between the steel bumper plates. These have levelled edges which fit into hardened conical steel seats. Steel valves are not sufficiently flexible to be satisfactory for cement grout service. The rubber inserts were replaced at frequent intervals. If the seating gets cut by the action of grout, it is repaired by welding and refacing the bevelled seat.

Liners :

The liners of the liquid end of the pump were of the pressed-in-type inserted within the shell of the liner. They are made of case hardened steel having a highly polished wearing surface.

Pistons :

The original pistons were removed and replaced by pistons made of medium-soft rubber moulded on to a steel core so that the whole may be fastened to the end of the piston rod. These pistons are cylindrical in shape with each end flared or enlarged, so that when these are fitted into the cylinder they will be compressed in such a way as to sweep the inner surfaces of the liner clean of grout at each stroke, thereby preventing grout from passing the ends of the pistons. Grouting specifications cannot be met unless the pump, especially the pistons and liners, are kept in first class operating conditions.

Piston Rods :

Piston rods are made of medium-hard case hardened steel and are of uniform diameter. They are milled square or provided with milled surface at the cross-head end, to facilitate their removal. Pipe wrench should never be used on the polished surface of a pump rod. A smooth surface on the rod is essential to reduce wear on the pump packing.

Packing :

For packing liners and cover plates, asbestos sheet packing was used with good results.

Lubrication :

Drip oilers are provided for keeping the liquid end rod lubricated. If the packing is too tight, the rods will overheat and cause trouble. For maximum service oil SAE 20 or 30 should be used. A metal pan is kept below the pump to catch the oil so that it will not be wasted.

Grout Mixer

The grout mixer consists of a rectangular tank with a semicircular bottom mounted on skids as shown in Figure 4. It is 4 ft. long and 3 ft. wide with a capacity of 421 cft. There is a central horizontal shaft with paddles attached to it. The shaft is supported at either end by bearings. The body is made of $\frac{1}{4}$″ plate. A handle is provided at one end of the shaft for rotating the shaft by manual labour. The mixer was fabricated in our workshops. It is provided with a 4″ outlet at one end of the cylindrical bottom and fitted with a 4″ core valve for opening and closing the opening. The valve is operated by means of a vertical handle provided on the side of the mixer where the mixer man stands.

There is a platform on either side of the mixer for keeping stock of cement as well as for the mixer man to stand. A removable screen was provided on top of the minor drum to prevent clotted cement and jute pieces from going into the mixer. Since the top of the mixer was open, it was easy for washing and cleaning. It was well maintained and gave excellent service.

Agitator Sump

After the grout has properly been mixed in the mixer it is discharged into the agitator tank which acts as the sump for the grout pump. The grout is prevented from settling down while it is being pumped. The agitator tank consists of a vertical cylindrical tank 3′ diameter and 2′-6″ height placed below the mixer so that the grout discharges directly into the agitator through the mixer valve. A $\frac{1}{4}$″ mesh strainer is provied on top of the agitator so as to remove any pieces of jute bags, strings, wires or other foreign matter that may be dropped into the mixer. There is a central shaft provided with paddles at the bottom which is turned manually by means of a handle at the top of the tank in order to keep the grout from settling down. The agitator has got a capacity of 17 cft.

Water Meter

A water meter of suitable size is fixed to the side of the mixer. All water required for mixing grout is passed through this meter which reads directly in gallons.

Pressure Gauges

Reliable pressure gauges are always essential in in pressure grouting. They constitute the principal index to the behaviour of the hole and the resulting stresses that are set up in the rock or superimposed structure. There should always be two gauges in the grout line—one at the pump and the other at the grout hole. "Hook Up" for controlling the pressures during the progress of grouting. The ganges used were of the heavy duty type. The gauges were protected from grout by means of gauge savers.

The gauge saver consists of a short length of oil or grease filled siphon between the gauge and the grout supply line. Diaphragm type of gauge saver filled with glycerine was also used. Further protection for the gauge was given by installing an air dome in the grout supply line. This reduced the flicker of the needle with each stroke of the pump and thereby caused less wear on the moving parts of the gauge.

The pressure gauges used were of the Ashcroft type with 6″ dial graduated from 0 to 300 lbs in 10 lbs intervals.

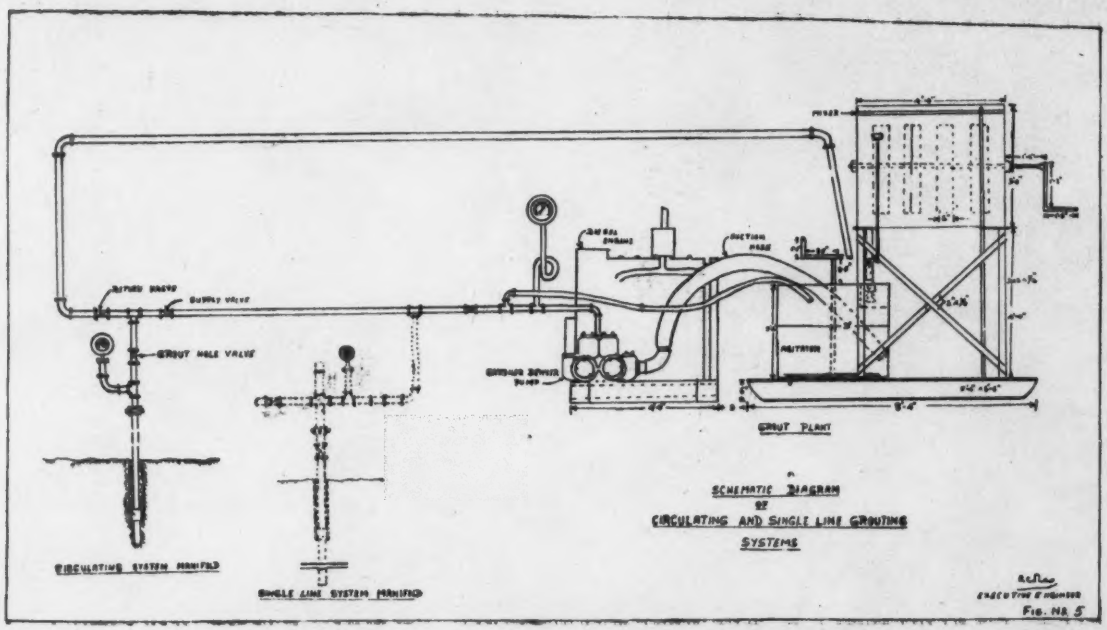
Pipes and Fittings

1$\frac{1}{2}$″ standard G.I. pipes were used for the grout supply and return lines from the pump. These were connected to the header at the top of the hole through single lengths of high pressure hose.

1″ G.I. pipes were used for water and air lines.

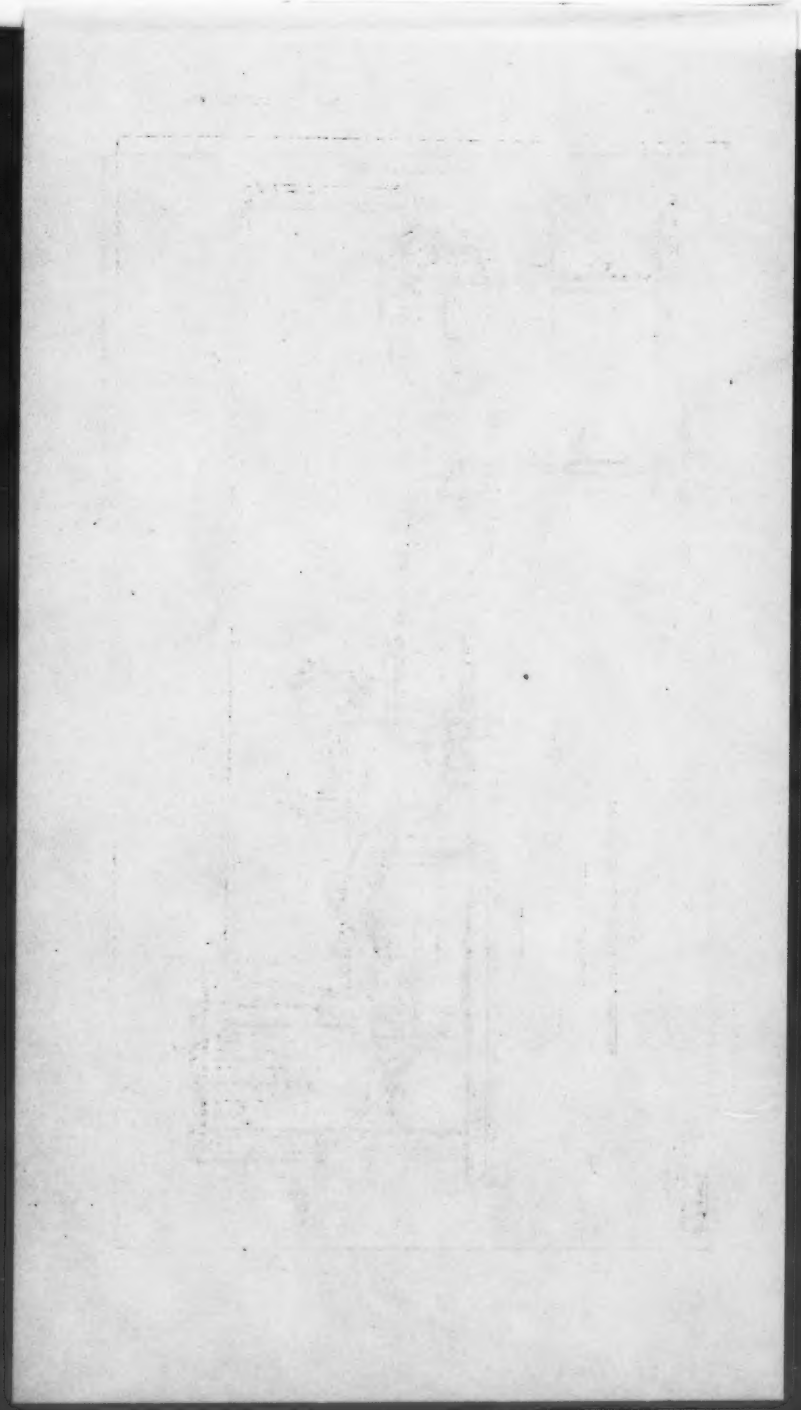
Grout Header

The connection manifold at the hole known as header consisted of a series of 3 valves by which water or grout pumped into the line could be shut off in the line, pumped into the hole or wasted or kept in circulation with the grout hole shut off. A pressure gauge was installed on the grout supply line at the



SCHEMATIC DIAGRAM
OF
CIRCULATING AND SINGLE LINE GROUTING
SYSTEMS

FIG. NO. 5



pump and at the header near the hole to observe the pumping and static pressures on each hole as it was grouted. Photo shows the details of the header fitted to a hole.

Grout Valves

The valves used on the grout lines were of the quick acting, straightway, lubricated plug type valves. This lubricated type helped in keeping the valves clean and serviceable during prolonged grouting operations.

Grout Hose

The pump suction hose was 4″ inside diameter and 10′ long. This was of the flexible type and it was provided with flanged connection at one end for attaching to the suction end of the pump.

The grout hose was 1½″ I-D 3-Ply wire braided in 25′ length with suitable steel right hand threaded joint couplings to withstand a maximum working pressure of 500 psi and a bursting pressure of 2000 psi. These gave excellent service. The use of hose reduced much of the costly pipe fittings in making connections to grout holes.

Tools

An adequate supply of the following tools and accessories should be provided at each plant. (*i*) A set of socket wrenches, Ring spanners and slide wrenches. (*ii*) A set of chisels with curved ends, for cleaning the inside of the pumps. (*iii*) Caulking iron and hammers as well as lead wool. (*iv*) Grease, lubricating oil and gland packing.

Connections to Grout Holes

There are a number of ways of making connection to the grout hole. This will depend upon the type of pump being used, and the methods used in grouting, eg., single stage grouting, multiple stage grouting or packer grouting.

The grout lines used at Hirakud were mostly of the circulating system.

This system employed the use of a return line from the manifold to the agitator as shown in figure 4.

The grout pump is operated at constant speed and the pressure to the hole is regulated by manipulating the valves on the manifold or header .This arrangement was found to be very useful in grouting holes where the rate of injection was very slow. It prevented the cement on the grout from settling in the chambers of the pump and in the supply line. The manifold in the circulating system has control valves in addition to the grout hole valve on the nipple at the top of the hole.

When starting grouting operations, the grout hole valve is closed and the two control valves are opened. This permits grout to circulate through the supply line and return to the agitator sump. As soon as grout flows from the outlet of the return line into the sump, the grout hole valve is opened. The desired pressure is obtained by adjusting the return line valves or in some cases by regulating the speed of the pump.

When grouting large cavities the return valve is completely closed to direct the full grout flow into the hole. When this is done, the return valve must be opened periodically to replace the residual grout in the return line with fresh grout. On completion of a hole, the grout hole valve and the control valves are closed. Wih these valves closed, the manifold is disconnected and moved to the next hole to be grouted while the grout is still circulating in the system unless it is necessary to add additional length of pipe.

Figure 4 shows the method of connecting the grouting header to the pipe nipple at the top of the grout hole top when the hole is being grouted in single stage from the of the hole, or when the upper portion of the hole is being grouted after the bottom zones have been grouted with packers.

A pipe nipple of about 2½ length is inserted into the hole with 6″ projecting above the hole. It is caulked in place with leadwool. The annular space between the pipe and the hole is filled with thick grout and allowed to harden before grout pressure is applied. A plug valve is screwed on to the nipple followed by a short nipple and union to which the header is connected.

Figure 5 shows the methods of connecting the grouting header to the hole when a packer is used in the hole. This was the method most commonly used as all the holes were grouted with the use of packers. The packer is fixed in the hole at the desired level and the packer pipe projects above the top of the hole with a plug valve and a union attached to it for connecto to the grout header as shown in figure.

After the completion of grouting the packer valve and the header control valve are closed. The header is disconnected and moved to the next hole to be grouted.

Packer

Packer or expanding plugs are devices to be inserted in holes for the purpose of localising the applied pressure to certain zones within the hole. A number of types of packers have been developed for water-testing foundations through drilled holes. The type of packer extensively used at Hirakud consists of a soft rubber collar mounted on a pipe with a device for expanding it against the cylindrical surface of the hole so as to effect a seal. Packers of this type are satisfactory in hard rock where the surface of the hole is drilled true. In soft or broken formations some diffidulty was experienced in seating the packer in the hole due to surface irregularities and caving from the sides of the holes.

These packers are made at site by the grouting crew, in different lengths and for different sizes of holes according to requirements. The rubber sleeves alone are purchased from rubber manufacturing companies. The sizes of rubber sleeves used for different sizes of holes are given below.

Size of hole	*Size of rubber sleeves.*		
	I.D.	O.D.	Length
EX	$\frac{3}{4}$″	$1\frac{3}{8}$″	4″
AX and 2″ Wagon Drill hole	1″	$1\frac{25}{32}$″	4″
BX	$1\frac{1}{2}$″	$2\frac{9}{32}$″	4″
NX	$1\frac{1}{2}$″	2″	4″

On account of the limited size of the gallery, the packers used for the holes inside the gallery were made up by joining together 5 ft. sections of pipes.

Diamond Bits

Diamond core drill bits were used for drilling all the high pressure grout holes and drainage holes. The different sizes and types of bits used are describedinthe Table—. Bits of sizes A x, and E x were used for grout holes and N x sizes were used for drainage holes.

There is no resetting service available in this country All used bits had to be sent abroad for resetting. Some of the bits which were used during the earlier investigation period and sent for resetting in April 1955 were received back after resetting in January 1956. The methods by which these were obtained are described in the following paragraph.

Resetting of Diamond Bits

Total of 231 diamond bits were sent to M/s Voltas Ltd. for resetting. These bits were originally used during the preliminary investigation stage in different rock foundations. The worn out crowns alone were despatched to their principals in U.K. There the diamonds were extracted from the crowns. A vast variety of stones were extracted and these were cleaned and carefully sorted both as to size and quality. Both Congoes as well as Bortz diamonds were extracted. The methods by which these were used in resetting the bits are described below.

(1) Congo Diamonds

Congo diamonds were extracted from 53 bits. These diamonds varied in size from 16 stones per carat to 4 stones per carat. 39 of Bx size bits were made out of these. The scrap diamonds that were extracted were credited to the Project at Rs. 8/- per carat.

Cost Details

(1) Cost of 39 pieces size Bx blank core bit.. manufacturing and setting charges Rs. 59/- each =Rs. 2301/-

(*b*) Total usuable diamonds recovered from worn out bits which has been re-utilised for resetting these 39 pieces Bx core bits (387.35 carats)

(*c*) Total new congo diamonds added for resetting these 39 pieces Bx core bits; 117.10 carats Rs. 37/- per carat. =Rs. 4332-11

(*d*) Air Freight charges for sending the bits from Calcuta to London and back, insurance and customs duty on the total value of bits, clearing charges etc. 1521 15 0

Total (a+c+d) = 8155 10 0

(*e*) Less scrap diamonds 438.65 carats @ Rs. 8/- per carat. 2789 3 0

Total Rs. 5366 7 0

(2) Bortz Diamonds

Bortz was extracted from 178 bits. The size of stones varied from 8/16 to 30/60 per carat and they were of different qualities. These were mixed together to form an E grade average plus a slight strengthening of R and G qualities and these were set with the mixture which was mostly 16/30 size and mostly E quality.

Cost of Resetting

Total carats available=790.65

Total usable diamonds recovered from worn out bits 724 carats of mixture of 16/30 and 30/60 and 67 carats of 8/16.

(*b*) cost of 178 pieces of Ex blank bit. manufacturing and setting charges @ Rs. 37-8-0 each Rs. 6675/-

(*c*) Total new E grade diamonds added for resetting these 178 pieces of Ex core bits.

476 carats for resetting 160 pieces Ex core bits with 16/30 stones per carat and 113 carats for resetting 18 pieces Ex bits with 8/16 per carat.

Total 589 carat @ Rs. 32/- carat Rs. 18848/-

(*d*) Air freight charges for these reset bit from London to Calcutta, insurance, import duty etc. 2374/-

Total = 27897/-

(*c*) Less scrap diamonds recovered 370.15 carat Rs. 8/- Carat. 2961/-

Total =24936/-

Upheaval Gauge

During the progress of grouting, upheaval gauges were fixed at some points in the gallery for noting any uplift caused due to excessive grouting pressure. It consists of a standard $\frac{3}{4}''$ pipe with its lower end anchored by grout in the bottom of the hole. Above the anchorage it is encased in a $1\frac{1}{2}''$ pipe. The annular space between the two pipes was caulked with leadwool at both ends. The $1\frac{1}{2}''$ pipe is encased in a $2''$ nipple and the annular space caulked with leadwool and filled with grease. After the pipe has been anchored by pouring grout through it, it is held in a vertical position by maintaining a strain on the top while the hole is being filled with lean cement mortar. The strain is held until the mortar sets, thus restraining the pipe against excessive deflection due to carrying its own weight as a column. Any heaving or lifting of foundation rock is recorded on the dial gauge through the $4''$ cap welded to the $1\frac{1}{2}''$ pipe. If a progressive increase of as much as $0.01''$ occurred it is considered as a warning as to safe pressure being exceeded. As soon as this occurred the header pipe was removed from the hole and the grout allowed to flow out till the original position of the structure was reached and the grouting was resumed at reduced pressure.

Relief Valves

This is put on the grout delivery line from the grout pump and just before the pressure gauge and just beyond the bypass valve on delivery line. The relief valve is previously set at the desired maximum pressure with the proper size of nail. When the pressure tends to rise above the desired maximum limit the nail gives way and the valve blows off relieving the pressure. When this happens, it has to be set again before resuming further pumping. This was very helpful and it always ensured that the pressure never rose above the desired maximum pressure.

Speed of Drilling and Grouting

Four diamond drills were working during the entire period. Each drill (CP-55A) gave an average progress of 15 ft. per shift while drilling the "A" holes, and 10 ft per shift while driling 'D" holes. The maximum progress on certain days has been as much as 20 ft per shift and 15'/ shift respectively on the "A" hole and "D" hole drilling.

The heavy duty drills used on the Left Spillway gave an average progress of 8 ft./ shift. Five such drills were in operation during the entire period. The average time taken for grouting a hole was 4 shifts of 8 hours each.

Records of Drilling & Grouting

Careful observations were made daily of the different operations during the progress of drilling and grouting. All these are recorded on standard daily progress report forms maintained for this purpose and sent to office for record. Tables 2 & 3 show the typical forms for drilling and grouting records respectively. The field data are neatly entered in the record books maintained in the office. Drawings showing the plan and sections of the foundations along the line of grout curtain was always maintained up to date during the progress of drilling and grouting.

Handling of Cores

The cores obtained from drill holes were carefully preserved in wooden core boxes containing suitable sizes of compartments depending upon the size of cores. The cores were properly numbered and marked for depth and core loss on distance pieces kept between the consecutive runs. The usual size of box was $5' \times 1'$ but the actual size varied according to the size of the core to be put in. The core box contains 5,6, and 9 compartments for Nx, Bx Ax and Ex sizes respectively. When different sizes of core have to be accommodated in the same box, the compartments are suitably altered at site according to requirements. Photo 3 shows a core box containing Ax cores. The dimensions of the different sizes of core box are shown in Table 4.

Labour

The drilling and grouting crew consisted of well trained personnel who have been working here from 1951-52 season. Work was carried on continuously in 2 shifts and when ocassion warranted, it was done in 3 shifts also. The details of the allocation of labourers for different works are given below.

Category of labour	*No. of men*	*Rate of pay including D.A. per month.*
Assistant Foreman ..	1	231/-
Chargeman ..	1	187/-
Observer ..	1	120/-
Work Sarkars ..	7	105 to 125/-
Machine tool operator	1	140/-
Electrician ..	1	165/-
Wireman ..	1	105/-
Compressor driver	4	110/-
Drillers ..	4	105 to 145/-
Apprentice driller ..	5	80/-
Pump operators ..	9	105 to 115/-
Fitters ..	16	80 to 140/-
Helpers ..	29	65 to 70/-
Mazdoors ..	25	40/-
Chowkidars ..	6	40/-

25.0 STATISTICAL FIGURES

Feature.	*Length of Section.*	*Maximum height of section*	*No. of holes drilled and Grouted*	*otal footage drilled and Grouted*	*Total cement placed in rock*	*Average per liner Refoot Marks in rock*
1. High pressure grouting				In rock		
a. Left spillway ..	1589	152	113	6058	2464	0.407
b. Right spillway and Power Dam ..	2150	200	125	7402	2226	0.35
2. Drainage Holes Drilling..	....	....	....	....	....	....
a. Left Spillway ..	..	....	61	3768	....	....
b. Right Spillway and Power Dam ..	....	....	....	....	....	....

26.0. **COST DATA**. The Cost Data for drilling and grouting is given below :

	Type of machine used	*Rate per foot.*
1. Drilling high Pressure grout holes $1\frac{1}{2}''$ to $3''$ and $70'$ to $90'$ deep	Petrol Engine Driven diamond drills.	Rs. 25/-
2. Drilling high Pressure grout holes $1\frac{1}{2}''$ to $3''$ and $70'$ to $90'$ deep.	Pneumatic Diamond Drills.	Rs. 18/-
3. Drilling Drainage holes $3''$ diameter.	Petrol Engine driven diamond drills.	Rs. 35/-
4. Drilling Drainage holes $3''$ diameter.	Pneumatic drills.	Rs. 26/-
5. Grouting High Pressure Grout holes 70' to 90' deep.	Gardner Denver grout pump with caterpiller Diesel Engine.	Rs. 5/-

Phato 3— Core box showing the arrangement of cores recovered from grout hole.

Summary

The foundations at Hirakud Dam consisted of hard and massive rock with numerous faults, fissures and crushed zones. The method of treatment consisted of preliminary low pressure consolidation grouting followed by a deep grouted cut off and drainage arrangements.

After the completion of consolidation grouting, pipes have been embedded in the floor of the drainage gallery or sill of sluices as the case may be at regular intervals along two lines parallel to the axis of Dam, for subsequent drilling of high pressure grout holes and drainage holes. After the Dam has come up above spill-way crest level, the drilling and grouting operations for the curtain and drainage were started and completed before storage in the reservoir commenced.

Drilling of holes from the gallery was accomplished by means of special pneumatic diamond core drills. Stage grouting method with packers was adopted using Gardner Denver grout pumps.

Acknowledgements

I am greatly indebted to Sri M. S. Thirumale Iyengar B.E., M.I.E, I.S.E., Chief Engineer Hirakud Dam Project for having given me this opportunity for carrying out the high pressure grouting work at Hirakud Dam and for the permission given to me to prepare this paper. I am also grateful to him for the valuable advice and guidance given to me in the preparation of this paper.

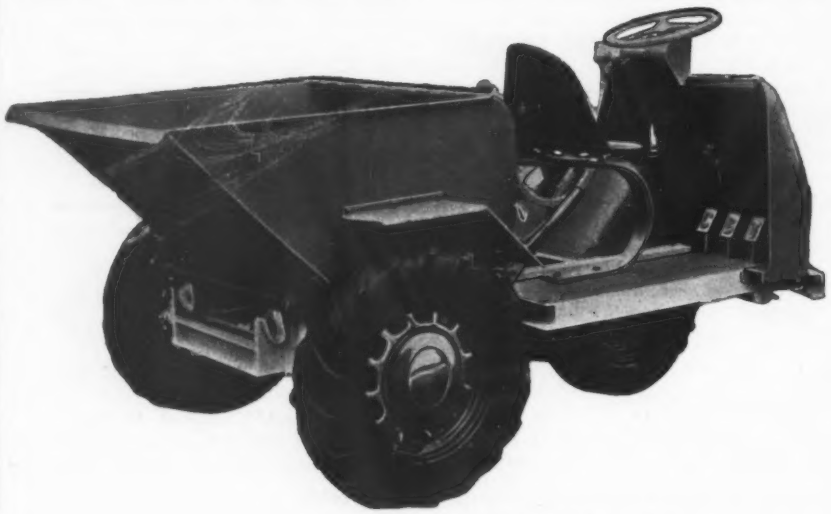


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Table No. 1

Specification of the Diamond Drills used.

Type & Make of the Machine	*No. of Machines*	*Type & Make of Engine*	*Drive.*	*Feed.*	*Bit Speed RPM*	*Weight of Drill and Frame*
(*A*) DIAMOND DRILLS.						
1. Craelius type XF	4	Albin petrol Engine Type AL 22	Petrol 10 HP	Automatic Pressure controlled & screw feed	250 500 & 750	520 Kg.
2. EJ Longyear & Co.	2	Waukesha Petrol Engine Model FC.	4 Cylinder water cooled heavy duty, industrial type Petrol Engine 20 HP.	Hydraulic Feed. (Oil)	1800	
3. Canadian Longyear Ltd.	1	Buda Model 4D1226	4 Cylinder, Water cooled, heavy duty & industrial type, Diesel engine 28HP	,,		
4. Sprague & Henwood Type G-3		Willys' jeep Enginge	Petrol 27HP	Screw Feed.		
5. Sprague & Henwood.	1	Buda Model BM No. 10785 A	4 Cylinder water cooled heavy duty industrial type Petrol 27HP.	Hydraulic (Water)		
6. CP 55 A Chicago Pneumatic.	4	Rotary Air Motor 6 blades.	Air	Screw feed length of feed : 24″		160 lbs.
(*B*) GROUT PUMPS Gardner Denver Duplex, double acting reciprocating pump. 4″ × 6″	10	Caterpiller Diesel engine Model D 3400	Belt Drive HP 27			4 Pumps used for high pressure grouting
(*C*) AIR COMPRESSORS						
1. Broomwade 250 CFM	4	Gardner Engine	Diesel			
2. Consolidated Pneumamatic 315 CFM.	3	Jap Engine and Ruston Engine.	Diesel.			

ITEMS 1, The Craelius Drill had the water pump attached to the drill on the same frame and run by the same engine by belt transmission.

2, 3 & 4. had hydraulic oil pump fitted on the machine itself. Water for drill was supplied by separate (petrol driven Novo) pumps.

ITEM 5. Had the hydraulic run by water pressure.

ITEM 6. The pneumatic drills were used for drilling high pressure grout holes inside the foundation drainage gallery. These drills were used inside the gallery because (*i*) there is no trouble due to exhaust smoke, (*ii*) on account of restricted space in the gallery, (*iii*) easy portability and (*iv*) operated by one man.

Table 2

Daily Drill Report

Dam Site. . . . . Hole No. . . . . Elevation. . . . . .

Drill No. . . . . Start of Shift. . . . . .

End of Shift. . . . . .

Total. . . . . .

Runs		*Length*	*Material*	*Core*	
From	*To*			*Feet*	*Inch*

Supplies *Total*

Gas.	Oil.	Remarks :—

Water Leakage :— *Runner*. . . . . .

Foreman. . . . . .

Table 3

Field Grouting Report

Date. . . . . *Shift*. . . . . *Beg : of Shift*. . . . . *Page*. . . . .

Hole No. . . . . *Class*. . . . . *Type & Dia*. . . . . *End of Shift*. . . . . *Plant*. . . .

Station. . . . . *Feature*. . . . . *Pump*. . . . . .

Material	*Placed*	*Wasted*	*Caulking*
Bags of Cement			
Admixtures			

Date drilled. . . . . Elev. of hole. . . . . Elev. of bottom. . . .

Date washed. . . . . Incl. of Hole. . . . . Observer. . . . . .

Date tested. . . . . Depth of Hole. . . . . Plant Engineer. . . . .

*Cap or depth of seal.

TIME	CEMENT USED			PRESSURE PSI			
15-min. period. Grout take or change of W/C Ratio.	*Total Bags.*	*Bags per period.*	*Bags per hour*	*W/C Ratio*	*Pump*	*Header*	*Actual*

Remarks

NOTE : Reserve this space for notes relative to grouting, such as "Injected grout, Water (grout) take 15 G/M. Reduced W/C ratio (pressure) to seal leaks, water (grout) issuing from 53.C hole capped, large (small) leaks 15′ D. S. (U. P.) from 9-C1., leak sealed, Return line plugged, Washing lines header etc.

*Enter depth of zone which packer set. All depth must refer to top of hole.

Table 4

Table of Core Boxes.

L=5′-1½″, I=5′-0″, T=0′-¾″, T_1=0′-½″, t=0′-½″.

Core box.	*Core Size.*	*B.*	*b.*	*D.*	*d.*	*No. of compartments.*
NX Casing	2 7/8″	15″	13½″	4¼″	3″	4
NX Coring	2 1/8″	14¾″	13¼″	3¼″	2¼″	5
BX Coring	1 5/8″	14½″	13″	3″	1¾″	6
AX Coring	1 1/8″	13¼″	11¾″	2¼″	1¼″	7
EX Coring	7/8″	14½″	13″	2¼″	1″	9

Table 5

Diamond Bits and Reaming Shells used for Drilling High Pessure Grout Holes and Drainage Holes

Size of Bit.	*Make of Bit*	*Quality of diamonds*	*Carat Wt.*	*Grade of diamonds*	*No. of stones per carat*	*Hardness of matrix.*	*Cost per Bit*	*Average life (ft)*	*Remarks.*
1.NX	Craelius diamy II Sp	Prime West African	18	R. Grade or AA.	30/60	45/55 on rocks well C scale and the leading edges of Special Wear resisting metal.	Rs. 661	40 ft.	Hard granitic rock.
	Truco	Bortz	14	R	30/60	H extra hard matrix (45-55) with special wear resisting metal at the leading edges.	Rs. 708/-	50	do
2.BX.	Craelius diamy II Sp	Prime West African	14		30/60	Do		40	do
BX	Truco		14		30/60	DO		55	do
BX Reset Bit	Truco	Congoe	13		16 per carat to 4 carat per stone	L Hard matrix (25-40)	Rs. 140/	100ft.	Shales and arkoses
3.AX	Craelius	Prime West African	10	R	30/60	(45-55 on rockwell C scale		50	Hard granitic rock.
	Truco		10	R	30/60	H extra hard matrix		70	
4.EX	Craelius diamond II Sp	Prime West African	7.0	G Grade or AA	30/60	(45-55) or rockwell C scale	Rs. 275/-	80	
	Truco Longyear	West African (Avearge) 5.5. 6.682	7.0	R E&G	30/60	H extra hard matrix	Rs. 287/- Rs. 414/-	100	
					30/60	45-50 rockwell	Rs. 259/-	100	
EX Reset	Truco	Bortz	7.7	E	16/30		Rs. 178/-		
Reaming Shells.									
NX	Strip type Craelius diamy II.	Prime West African	9.0 7.0	R R	30/60	45-50 Rockwell do			
BX			7.0	R		do			
AX			5.0	R		do			
EX			4.5	R		do			

Table 6

Life of Diamond bits and reaming shells etc., used for drilling curtain grout holes in Right Spillway & Power Dam.

Period :—January to May 1956, Total Footage drilled=7504Ft.

	NX	*BX*	*AX*	*EX*	*Total*	*Average life*	*Remarks.*
Diamond bits.	35	10	34	38	117	64.2	
Reaming shells.	3	3	5	14	25	300.0	
Core Lifters.	6	4	9	25	44	170.0	
Core barrels.	2	2	4	8	16	468.0	
Core Boxes.					254 No.		

Field Testing and Quality Control

By

S. BALASUBRAHMANYAM B.E.,C.E., A.M.I.E.,

Dy. Director, Hirakud Research Station, Hirakud Dam Prject

AUTHOR

The Research Station at Hirakud is already wellknown for its work in many fields of river research. This contribution, however, deals with only one aspect of its work, namely, Field Testing and Quality Control at the Dam site at the time of construction. This being the longest Dam in the world involving earth fill, concrete as well as masonry, the Station had to do a great deal of strenuous work, numbers of tests of cement samples, aggregates, sand, masonry. Density tests and Compaction tests sum upto several thousands. This constribution describes this aspect of the Stations work.

The statistical data in respect of the Hirakud Dam and Dykes should serve to convince one of the magnitude of the project ; for instance,

Maximum height of Masonry and Concrete Dam	200 ft.
Maximum height of Earth Dam :	195 ft.
Fill for Earth Dam and Dykes	64 crores cft.
Concrete in Dam :	2.27 crores cft.
Masonry in Dam :	1.49 crores cft.

This should also serve to emphasize the importance of ensuring that the construction conforms to the specifications, as infringement of specifications will mean undesirable incursions into the margin of safety, which in a water-storing structure of this magnitude may lead to disaster or disclose, during its performance, distress calling for otherwise avoidable protective measures. Inspection, control and necessary precautions at each step during the construction insure against such frightening possibilities. Field control of the quality derives its importance also from the fact that its efficiency reflects in the economy of the design and construction. If the field control can ensure close tolerances and narrow deviations from the optimum, the designer of the structure as well as the designer of the material like concrete with which the structure is built, need allow for margin of safety less than would otherwise be necessary. In the construction of not-so-important structures, it has been the practice so far to make the construction crew themselves responsible for the quality of the work also: in the construction of the Hirakud Dam and its ancillary works, testing and inspection for quality costituted a specialised function and the laboratory (the Hirakud Research Station) served this functional need, in conjunction with the construction crew.

The Hirakud Research Station which was responsible for the quality control had, as its assignments, investigations on borrow areas for the Earth Dam and Dykes, determination of the types and properties of soil available preparatory to design of the earth fill section, investigations for the sources of rubble and aggregate for masonry and concrete, design studies on concrete for the various locations of the Dam and other structures and the investigation on the silt load in the Mahanadi also. What follows here, however, restrict itself to 'Field Testing and Quality Control' and furnishes an account of the service performed as well as the mode in which it was performed.

The Organization

The Laboratory Organization reported directly to the Chief Engineer and was directly under the Chief Engineer's administrative control. This arrangement made, to a great degree, for the efficiency and the independence in the work of the laboratory in its day-to-day testing and request to the construction engineers to effect whatever rectifications were, in the laboratory's view, necessary. In cases of differences of opinion, which fortunately were very few, the matter was finally decided by the Chief Engineer.

The Laboratory was headed by an officer of the rank of an Executive Engineer, designated Deputy Director; the officers in charge of the various sections of the Laboratory, were designated Research Officers or Assistant Research Officers and were of the rank of Assistant Executive Engineers or Assistant Engineers. Each section had several Research Assistants and Analysts working mainly in the Laboratory and Inspectors and Assistant Inspectors for field work. The 'Personnel Chart' shows the organization pattern.

One feature of the Laboratory organization deserves special mention. Field inspection and testing procedures having been standardised, it was not particularly necessary to have all the ranks of the organization manned by men with engineering qualifications. At any given time, only one or two of the personnel at or near the top was or were with engineering qualifications. This arrangement helped release men with engineering qualifications for other jobs where they were essential.

Inspection and Field Testing

Concrete :

Realising that the quality of a structure depends as much on the quality of concrete as on the quality of workmanship, inspection was organised at each stage, from the production of concrete to its final placement. Such inspection comprised:

(*i*) examination, field testing and acceptance of aggregates and cement.
(*ii*) control of proportioning and batching of materials, and mixing of concrete.
(*iii*) examination of the adequacy of the clean-up of forms, foundation or base concrete prior to placing concrete, and
(*iv*) sampling and testing concrete and preparation of test specimens ; field tests included work-

Plate 1.—Clay Filling-Left Exploratory Tunnel.

Plate 2.—Sampling of Fill.

ability tests, unit weight and aircontent determination.

By observing the concrete at the plant as well as at the site and after performing necessary tests, the inspectors made any minor changes in the batching, necessitated by factors like temporary variance in the grading of aggregates or the variation in the free moisture present in them. Necessity for comparatively major changes in the mix was brought to the notice of the officers of the Laboratory, who as a routine inspected the work-sites and decided on necessary changes.

A report on the day's work which included particulars regarding the types of materials used, the production of concrete and its placing, improvements necessary and defects to be rectified was submitted to the Chief Engineer; this report was routed through the construction engineers so that they could furnish their comments for the Chief Engineer to issue instruction whenever necessary.

Masonry :

Masonry construction being a less mechanised operation than concrete, the work of the inspectors consisted principally of checking the quality of rubble, sand and cement used and adjustment of the batching of the cement and sand for mortar. The inspectors particularly sought to avoid rubble with excessively smooth surfaces or skins, excessively fine or coarse sand and sand with high percentages of foreign or undesirable impurities. Batching of materials for mortar being on a volumetric basis, they determined, each day and more often when necessary, the bulking of the sand used and adjusted the batching suitably. They helped the construction crew in their supervision particularly to ensure avoidance by the masons of excessive use of mortar, use of flat or unduly small stones in large quantities or the tendency to dump or pile up stones on the course of masonry which had just been built and had not had time to harden to the required degree. Sampling the mortar used, making test specimens for strength tests and submission of a report on the day's masonry work, formed part of the inspectors' work.

Earth Fill :

The inspectors assigned to the earth dam reassigned amongst the borrow area, the fill and the field laboratory. The borrow area inspectors saw to it that the excavation was restricted to approved locations, routed different types of soil to their destination and collected samples representing the types of soil actually used in the fill. The embankment inspectors ensured that dumping was done only on locations previously passed, that dumping was restricted to the quantity necessary for one layer of specified thickness over the area being dumped, that necessary moisture was added if it had not already been done in the borrow area and that the layer, after proper spreading, was rolled with approved types of roller. After the layer was rolled, the inspector took density samples and determined the in-place density of the soil in the compacted fill and passed the area for further dumping or required further rolling to be done, depending on the degree of compaction achieved in relation to the laboratory test compaction. Records were kept of the location of the day's dumping, the borrow area supplying the spoil, the details of sampling done in the rolled fill and the degree of compaction achieved.

The routine functions of field inspection on the

Plate 3.—Field Laboratory-Right Concrete Dam.

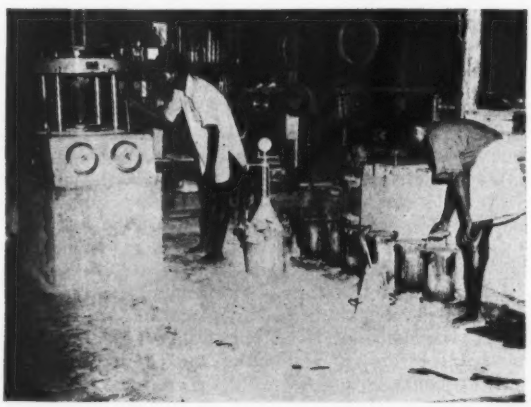


Plate 4.—Mortar without Entrained Air.

earth dam detailed above constituted only a part of the work devolving on the laboratory, for there were more interesting and more responsible assignments also. One such was the determination of the depth to which the cut-off trench should be taken for the main Earth Dam at its junction with the fill at the left abutment. Field permeability tests as well as permeability tests on undisturbed samples from the various depths were carried out before the final profile of the trench was specified. What made for an interesting problem was the presence of a tunnel on the abutment, parallel to the axis of the Dam, located in line with the main cut-off of the fill in the immediate vicinity. After weighing all factors involved, not excluding cost, the tunnel was filled with fat clay tamped in sloping layers with pneumatic tampers. Grout pipes were left in, in case further grouting is indicated to be necessary due to the consolidation of the fill.

For carrying out the necessary tests in the field, incidental to quality control on the job, the main laboratory i.e., the Hirakud Research Station, maintained as many as were necessary of smaller field laboratories suitably equipped. The field laboratories were required to attend to such tests as were necessarily to be carried out at site and would involve no more than routine test procedures. When the interests of the job demanded, impromptu laboratories were set up at site to meet specially urgent demands. During construction, one could often see right on any important job a tent which served as the control laboratory. For the Left and Right Concrete Dams, there was one field concrete laboratory at each site, with this difference that while the Left Dam field laboratory being nearer the main laboratory had most of its testing carried out there, the Right Dam field laboratory was more fully equipped as it was felt desirable to have as many tests as possible carried out there itself in view of the transport difficulties involved. The Right Dam field laboratory had its own 200 ton Compression Testing Machine, capable of testing specimens upto 12-in. height. These field concrete laboratories, established at the commencement of work in the Concrete and Masonry Dam continued till the end. The Earth Dam field laboratories were more in number; at any one time, as many as five or six functioned, including three at the dykes. Each of these field laboratories, concrete as well as earth dam, was in charge of one of the inspectors, designated *pro tem* Inspector-in-charge.

Inspectors in the field were guided by the instruction manuals covering inspection of Concrete and Earth Dam issued by the Hirakud Research Station.

This probably is as good a place to record one of the contributions of the Hirakud Research Station to the production and placement of improved concrete and use of improved mortar. The improvement referred to here is the improvement in the workability of concrete and mortar, resulting from the use of air-entraining admixtures. Having proved the advantages of the use of air-entraining admixtures in concrete, particularly with the type of aggregates available at Hirakud, the laboratory initially decided on the use of one of the imported commercially available admixture. In course of time, it went further and succeeded in developing from indigenous raw materials an acceptable airentraining agent which is now known as 'Aerosin-HRS'. Tests both in India and abroad proved the efficiency of 'Aerosin-HRS'. The use of this admixture was extended to masonry work also, where tests showed that the quality of the mortar used could be considerably improved. For those who would be sceptical unless precedents are pointed out, it should suffice to record that the entire quantity of concrete, totalling 20 lakhs cft. placed in the Hirakud Dam and 10 lakhs cft. of masonry built during 1955-56 season had in them the admixture of 'Aerosin-HRS'.

Statistical

The following information should interest the statistically-minded :

Concrete and Masonry Dam : Quantity of Cement Received at the Project :

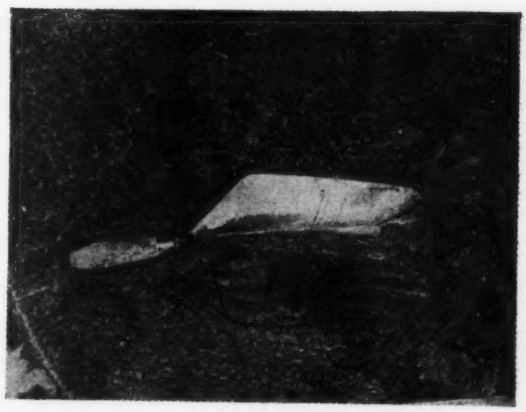
Number of composite cement samples tested :	3085
Number of tests on aggregates and sand :	4944
Quantity of concrete placed:	2.27 crores cft.
Number of concrete cylinders tested:	25980
Quantity of masonry in the dam :	1.49 crore cft.
Number of mortar cylinders tested:	56.46

Earth Dam and Dykes :

Quantity of earthfill :	64 crores cft.
Number of field density tests:	59,100
Number of field compaction tests :	2,300

Generally, in the case of concrete, the scale of sampling was such that at least one set of specimens was tested for the 28-day strength out of every 400

Plate 5.—Mortar with Entrained Air.

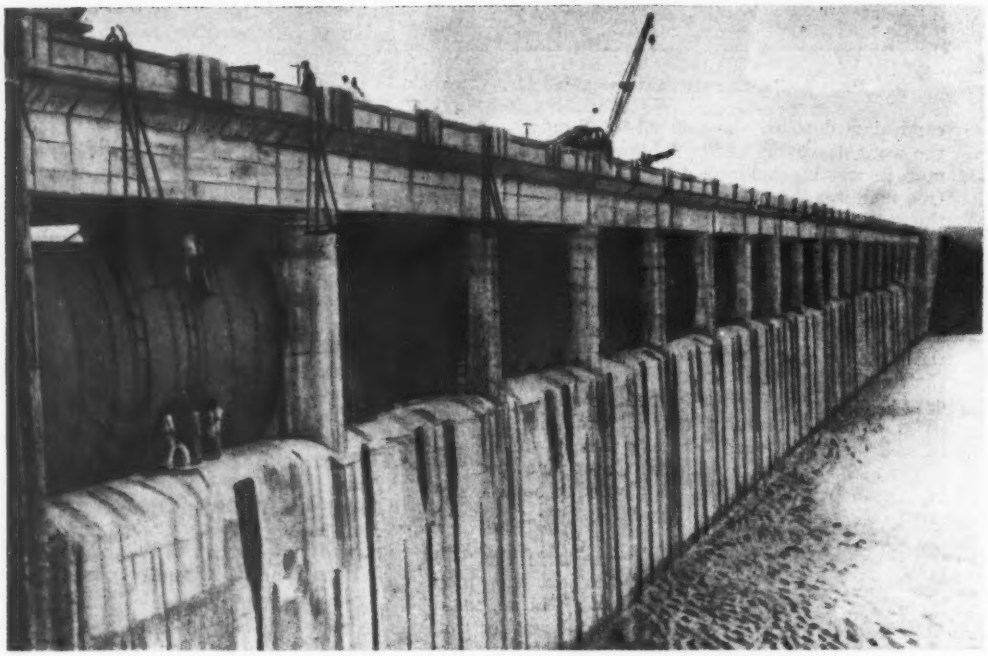


(*Continued on page* 38)

SLUICE GATES

FOR INDIA'S LONGEST MULTI-PURPOSE DAM

— HIRAKUD



Jessop & Co., Ltd., take justifiable pride in the fact that they designed, manufactured and erected 34 Radial Spillway Gates, each measuring 20 feet deep for a 51 feet opening between piers. They are electrically operated with provision for emergency operation by hand.

The picture shows the erection of some of the Jessop Radial Spillway Gates.

DESIGNED & MANUFACTURED ENTIRELY IN INDIA

by

JESSOP & CO. LTD. ENGINEERS

63, Netaji Subhas Road, Calcutta-1

JESSOP SLUICE GATES, OF THE FREE ROLLER, WHEEL AND RADIAL TYPES, ARE IN SERVICE AT THAMBRAPANI, KOPAI, DWARKA, BAKRESWAR, BRAHMANI, BOKARO, TILAIYA, DURGAPUR AND THE HIRAKUD MAIN DAM.

Gates in the Hirakud Dam Spillway

By

N. K. AGRAWAL, C.E. (Hons) M.S. (C.E.) Columbia

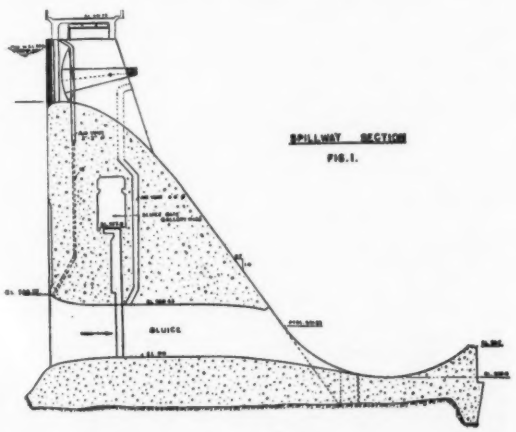
This contribution deals with the design manufacture and erection of Gates in the Hirakud Dam Spillway. Provision of such large sluices functioning under such large head in the project is a unique feature and provided new problems of constructon and erection, etc. Mr. Agrawal who was all along associated with this work, explains the various aspects of the problem and the way these were overcome.

The Spillways of the Hirakud Dam Project have been designed to pass a flood of 1.5 million cusecs. The passage to this huge quantity of water has been provided partly through the 64 deep bed sluices and partly over the crest of the Spillways. Two concrete Spillways, one 1260 feet long on the left channel and the other 780 feet long on the right channel, have been set in at suitable places in the 3 mile long Dam. The main features of the Spillways are:

(*a*) Sill level of the Sluices	EL. 510.0
(*b*) Size of each sluice	20′4″ × 12′ wide
(*c*) Crest level	EL. 610.0
(*d*) Road level	EL. 642.0

With maximum reservoir level at EL. 630.0 the sluices will discharge under a maximum head of (EL. 630.0—EL. 520.0) 110 feet. Provision of such large sluices functioning under such large head is in itself a unique feature in the Dam Construction Engineering of the world. This further provided new problems in construction of the sluice barrels and the controlling devices.

The crest has been provided with radial gates 20 ft. high and 51 feet clear span to control the water from crest to maximum reservoir level.



Sluice Gates

Sluice barrels have been constructed strictly according to the hydraulic requirements. The entrance has been bellmouthed to give a smooth entry and obtain a very high coefficient of discharge—aprroximately .87 (*Fig.* 1) based on the requirement of bellmouthing and facility of operation of sluice gates. The gates have been placed at a distance of 26 feet from the axis. A few feet upstream and downstream of this gate the sluice barrel has been lined with steel plate liner. Heavy reinforcement has been provided all round the barrel and rich concrete was used giving a theoretical 28 day strength of 3000 lbs/sq in. Actually the strength obtained was much more.

While concreting the sluice barrels, blockouts were left to take the embedded parts. Enough clearance was left in the blockouts for adjustment, alignment, plumbing and levelling of the embedded parts and concreting the blockouts.

Pockets were left in the sides of blockouts with anchor rods to take the hooks from the embedded metal work. Though the making of these pockets with anchored rods in them was a very slow, time and money taking problem while actually doing the concreting yet, once constructed, they facilitated the erection and adjustment of embedded parts very considerably.

Airvents

In order to avoid formation of vacuum and to assure smooth operation of sluice and emergency gates, air vents have been provided just downstream of both the sluice and emergency gate slots. Downstream of the main sluice a 4′ diameter, air vent has been provided. It starts as a formed 6′ × 2′ rectangular section at roof level of the sluice barrel and is changed to a 4′ square section. From there a 4 feet diameter formed vent is taken to EL. 590.0. Two vents are joined in one vent at this level which is ultimately taken out at EL. 515.0 downstream of the pier. No doubt the diameter of the vent is large, yet it presented several construction problems. Making the complicated form work at all angles and then removing it was time taking. In the portion where the vent again took out vertically after being horizontal a lot of waste was always collecting requiring constant clean up. General line of the vent is shown in *Fig. I.*

Air vent downstream of the emergency gate is a 18″ diameter section. Two vents are joined in to one at EL. 590.0 and exit at the top of the pier. The vents have been lined for the whole height. In addition to

facilitating construction this lining assured smooth working of the vent. Eighteen inch diameter M.S. pipes were made by bending and welding. The pipe was put in place and concreting done all round. Before concreting next lift another pipe was properly welded on to the lower length. Care was taken to see that atlest 1 foot of pipe is always projecting from the top of concrete, so that, no dirt goes in the vent during green cutting and cleaning of the concrete surface. Inspite of all these precautions the bends in the vents were far many and created some blocking.

Transport and stacking of parts

To handle approximately 5,000 tons of steel that made the sluice gates, guides, emergency gates and the cranes a separate yard 700 feet long and 150 feet wide was made. A butler hanger was erected at one end of the yard. A standard gauge railway line ran through the whole length of the yard into the hanger so that wagons bringing the gate parts can be directly taken and handled in the yard.

A track for a 14 ton gantry crane with a 30 feet span was laid along the railway line such that this crane could directly unload all the incoming wagons. The crane track was also taken into the hanger. Store rooms, office rooms etc. were made on either side inside the hanger. The whole setup was planned and made to facilitate proper stacking and easy, methodical handling of parts and their sending to the Dam in the required order.

One 15 ton crawler crane was also provided in the yard to stack the material properly and loading them into the trailer for shifting to the Dam as and when required.

Erection of sluice gate sill beam, liners, side guides and armature

The suppliers of the sluice gates are the German firms of M.A.N and Dortmundur Union through Escorts Agents Ltd., as their agents in India. The whole fabrication was arranged so that no single part weighed more than 5 tons except the gate leaves.

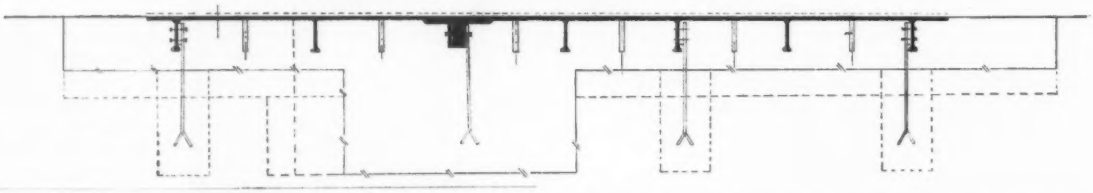
The embedded parts for the main gates consisted of the following main parts:

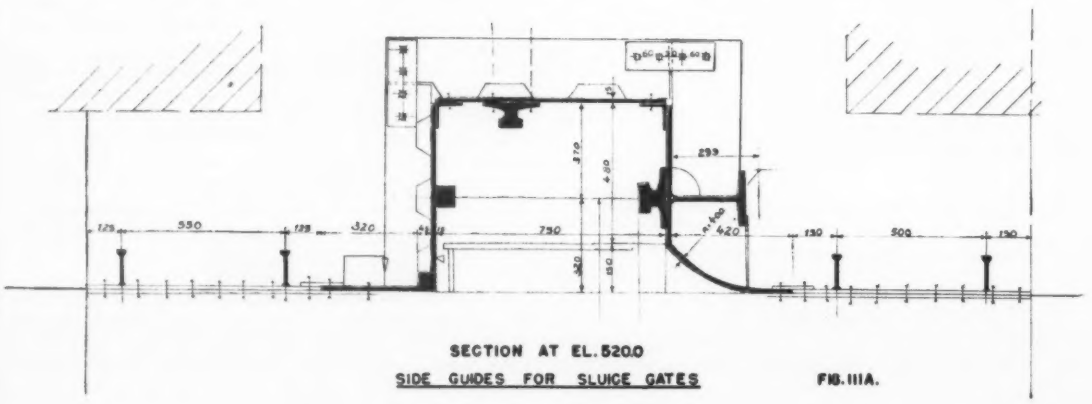
(*i*) Sill beam with liners
(*ii*) Side gides with liners
(*iii*) Top plates
(*iv*) Well armature consisting of six rails.

First step in the erection of these embedded parts consisted in alignment and marking out the Central line. A Crawler crane was placed on the upstream of the dam at an elevation of 510.0 above M.S.L. This crane lifted the sill beam and liners, travelled and delivered them at the required place. These were adjusted properly and grouted (*Fig. II*). As there were rails projecting under the liners it was found that external grouting left some hollows. Holes were then drilled through the liners and grouting done with a hand pump at a pressure not exceeding 10 lbs per sq. inch. The results obtained were satisfactory.

The side guides came in three pieces for either end, all the joints were bolted together by countersunk bolts as a lap joint. The central guide was a cup shaped piece of approximately 22 feet long complete with rails (*Fig. III A*). Liners were then fixed on upstream and downstream of this guide. The guide was delivered in the sluice by the crawler crane. One 7½ ton chain pulley block with long chains to handle upto a height of 60 feet was hoisted and fixed on a girder in the operation gallery at an approximate EL. of 570.0. The chain pulley block was used to hoist the vertical guide and liners in place. The anchor rods attached to the guide and liners were then bolted to the anchor rods in the pockets of the blockouts.

SLUICE GATE SILL BEAM & LINERS FIG.II.

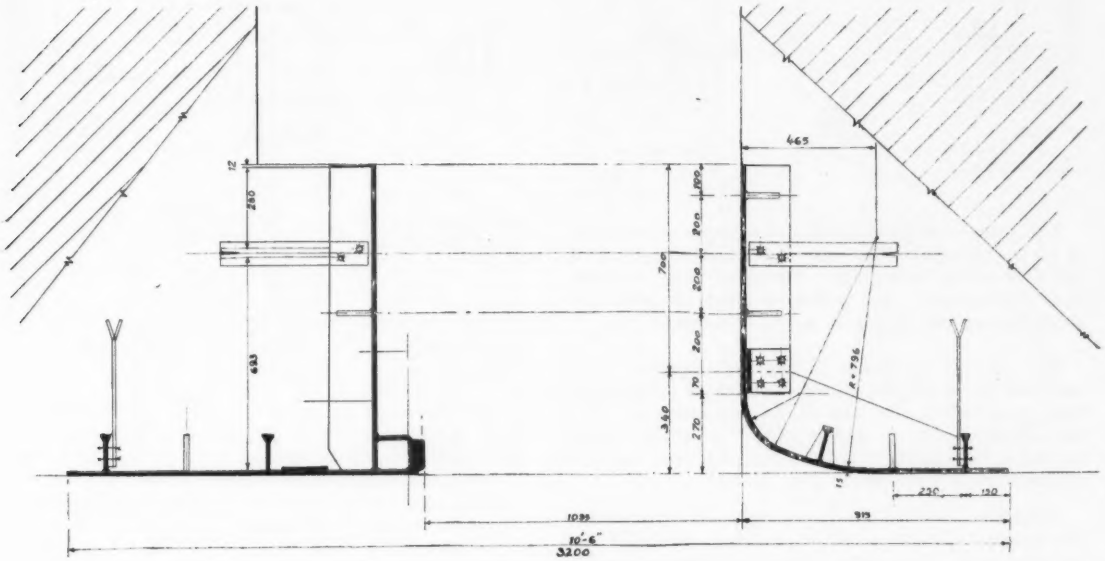




SECTION AT EL. 520.0
SIDE GUIDES FOR SLUICE GATES FIG. IIIA.

Similarly the top guide plates were delivered by the crane in the sluice and hoisted in place by the pulley block or a winch (*Fig. III B*)

The shaft armature rails were hoisted in place by a winch, adjusted with the help of a framework made locally and secured to the anchor rods of the



TOP EMBEDED PARTS. FIG. III B.

After all these were bolted together a caliper frame was introduced for alignment and plumbing. This frame called 'auxiliary appliances' by the suppliers was a frame work (*Fig. IV*) fitted with adjustable wedges. These wedges were touching the guide rails in the final adjusted position. Grouting was then done for the sides and top guides.

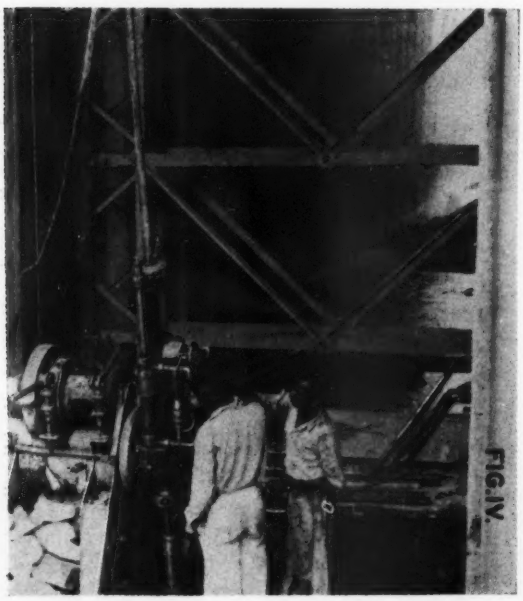
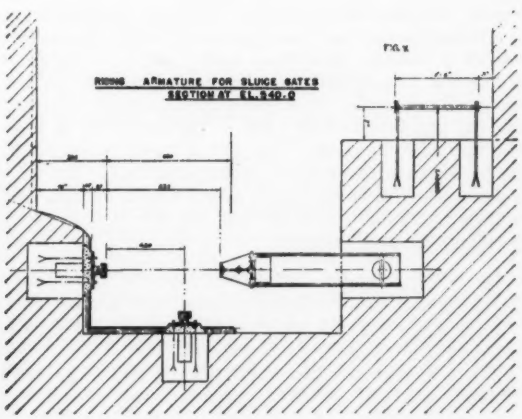


FIG. IV.

pockets in the blockouts (*Fig. V*). These were then grouted in place.

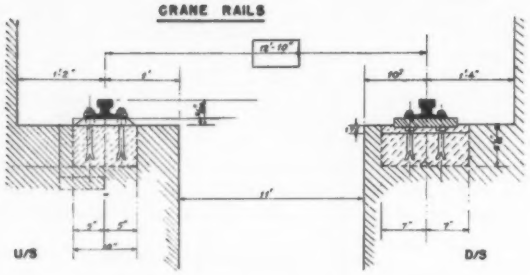


Cranes

After the guides and liners were in place the next step consisted in erection of the cranes in the 11′×23′ operation gallery. This gallery is perhaps the largest gallery in any dam in the world.

Rails were spread in the blockouts, left in the offsets in the gallery (*Fig. VI*). These rails were aligned, levelled and grouted in place. Approximately in the centre of the gallery the roof of the gallery was raised in a length of about a feet. A girder was fixed in this raised portion with two chain pulley blocks.

FIG. VI



The gates were to be carried by a wagon on wheeels. A meter gauge railway line was therefore spread on the floor of the gallery and concreted with the floor. At the entrance to the gallery a turntable was provided to turn this wagon at right angels. (*Fig.* X)

The number of sluices in the Left Spillway is 40 and that in the Right Spillway is 24. Five cranes have been provided in the Left Spillway gallery and 3 in the Right Spillway gallery. One of these cranes on either side is fitted with a movable crab and the others with a fixed crab (*Fig. VIIA*).

The frame work of the crane rests on 4 bogies and this frame takes the hoist rope drums, the hoist and travel motors. The control panel and operators cabin is suspended from the frame. A lifting beam with a single hook in the centre is suspended from hoist rope drums by these ropes. The rope has one end fixed to the frame, the other goes round a pulley on the beam, then round a pulley on the frame, again round a pulley on the beam and to the drum. The hoisting mechanism consists of a single motor operated rope drum hoists. Transmission of power from motor to the drum is effected through a worm gear reduction unit connected to a double reduction spur gear unit which is connected to and drives the rope drum unit of the hoist. Each drum is separately attached to either end of the beam. The hook is operated by a rope through a lever system. One end of this rope is attached to the hook lever on the beam and the other round a drum fixed in the crane frame. This drum has got a spring attached which keeps the rope tight in all positions of the beam.

In addition to the electrical operation the cranes have been fitted with mechanism for manual operation also. Rated capacity of each crane is 50 tons and they have been tested for 25% overload. The hoist speed is approximately 1.5 feet per minute and travel speed 90 feet per minute.

Power for operation of the cranes is supplied by gallery (*Fig. VIII*). Special insulators to support the conductors have been used.

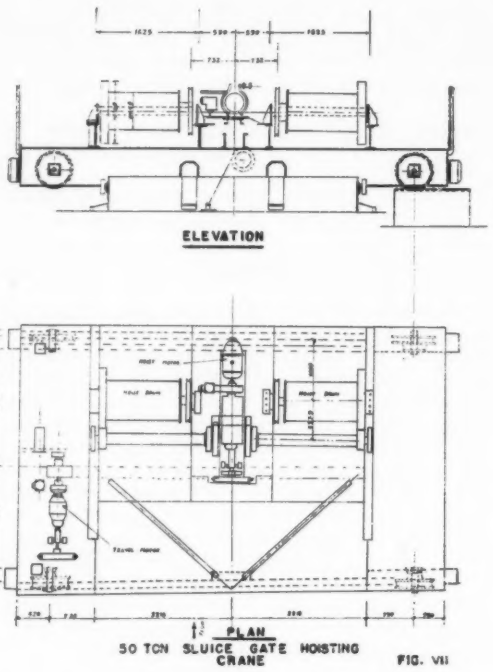
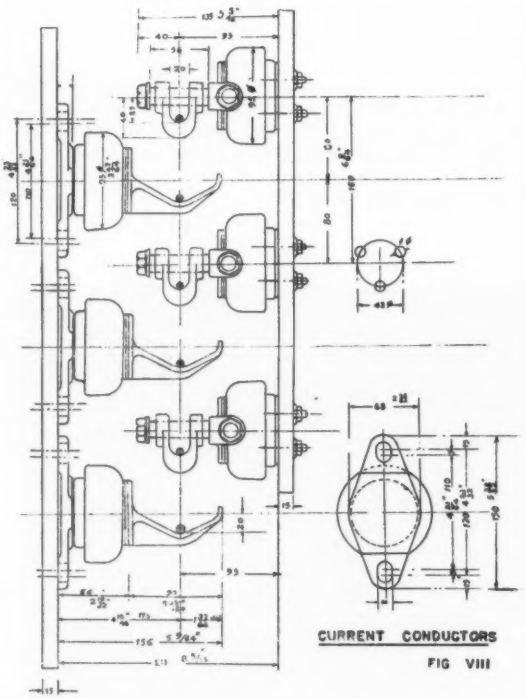


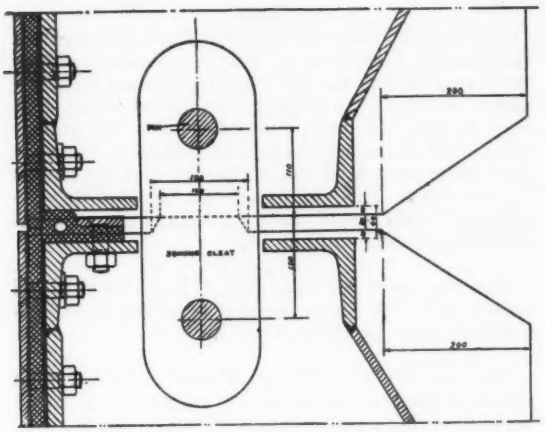
Fig. VII A



Gates

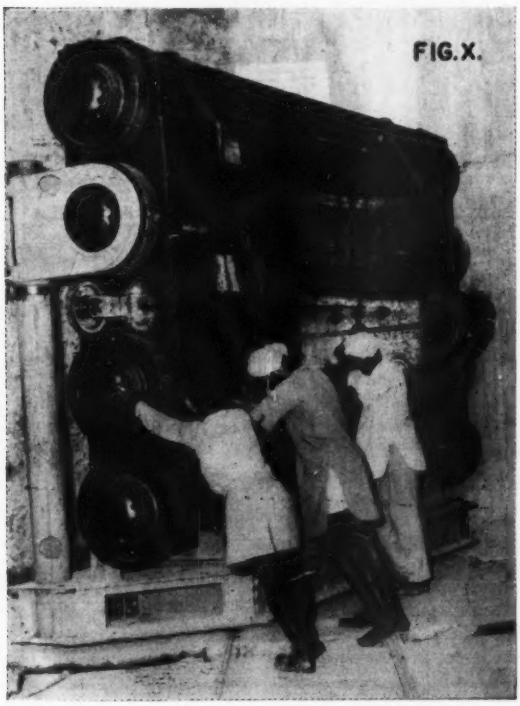
The 20′-10″ × 13′-1½″ gate has been fabricated in two leaves lower 9′10 3/16″ and upper 10′11 13/16″ for facility of transport and handling. Each leaf weighs 13 tons and, with rollers, each gate weighs 32 tons. Gate leaves consist of 8 nos. 2′ deep girders and two channels placed horizontally. One inch thick skin plate has been welded on top. Eight Rollers have been mounted on individual shaft on either side of the gate. The two leaves of the gate are joined together by two plates on either end with a pin going through the plates and the projecting plate of the lower leaf (*Fig. IX*).

The hubs for each roller axle have been line bored in the factory through two vertical girders. Rollers were received separately but mounted on the axles

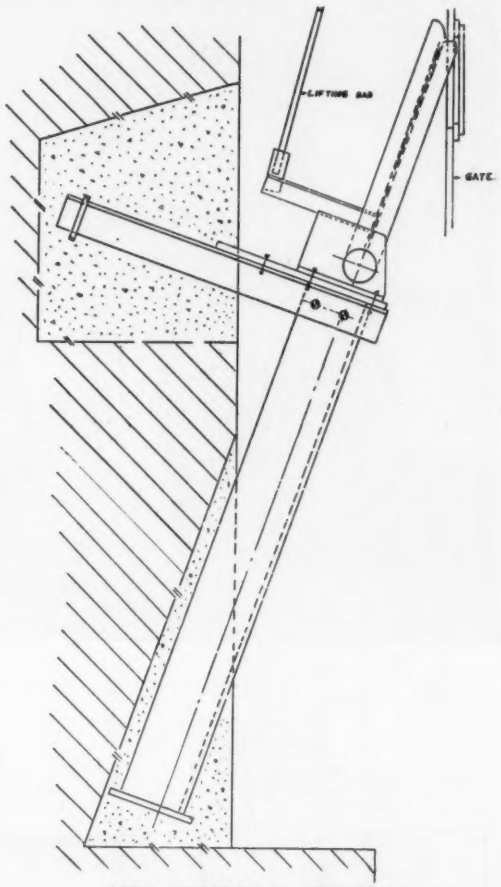


JUNCTION BETWEEN TWO LEAVES OF THE GATE. FIG. IX.

on grease packed roller bearings. The axle and rollers were assembled onto the gate in the yard. Care was taken to see that when assembled in each leaf, the guide rail contact surfaces of the wheels lay in a place parallel to the plane of the seal plate. The axle centre line at the wheel is 3/16 inch eccentric to the axle centre line at the support to allow adjustment for wheel alignment. Roller treads are flat to transmit the load to guide rails (*Fig X*).



The gates have not been designed for partial openings. In the full open condition the gate rests on a support embedded in concrete on the upstream face of the shaft. The support is operated manually from the gallery floor level. Two notches have been provided in the gate where the V groove in the support holds the gate. (*Fig. XI*).



GATE SUPPORT IN OPERATION FIG. XI.

The gates have been provided with smaller rollers at either end in a plane parallel to the plane of the gate. These rollers also have flat track and travels on the side guide rails.

After fitting the gates with all rollers and seals they were transported to the entrace of the operation gallery. A 15 ton crawler crane hoisted there in a vertical position and loaded it on the specially designed and fabricated transport wagon to hold the gate in the vertical position. The leaf was handled by the moving crab crane an lowered in the shaft just far enough so that the top was above the gallery floor. It was rested there on sleepers placed across the well on projections.

The second leaf was then brought over this one and attached to it by the pins. Full gate, thus ready, was lowered into its final raised position.

A special lifting beam has been designed and fitted to the crane with a hook in the centre to engage a slot in the gate for operation of the gate (*Fig. VII B*)

The details of the hook, pulleys and lever have been shown in figure *VII C*.

Seals

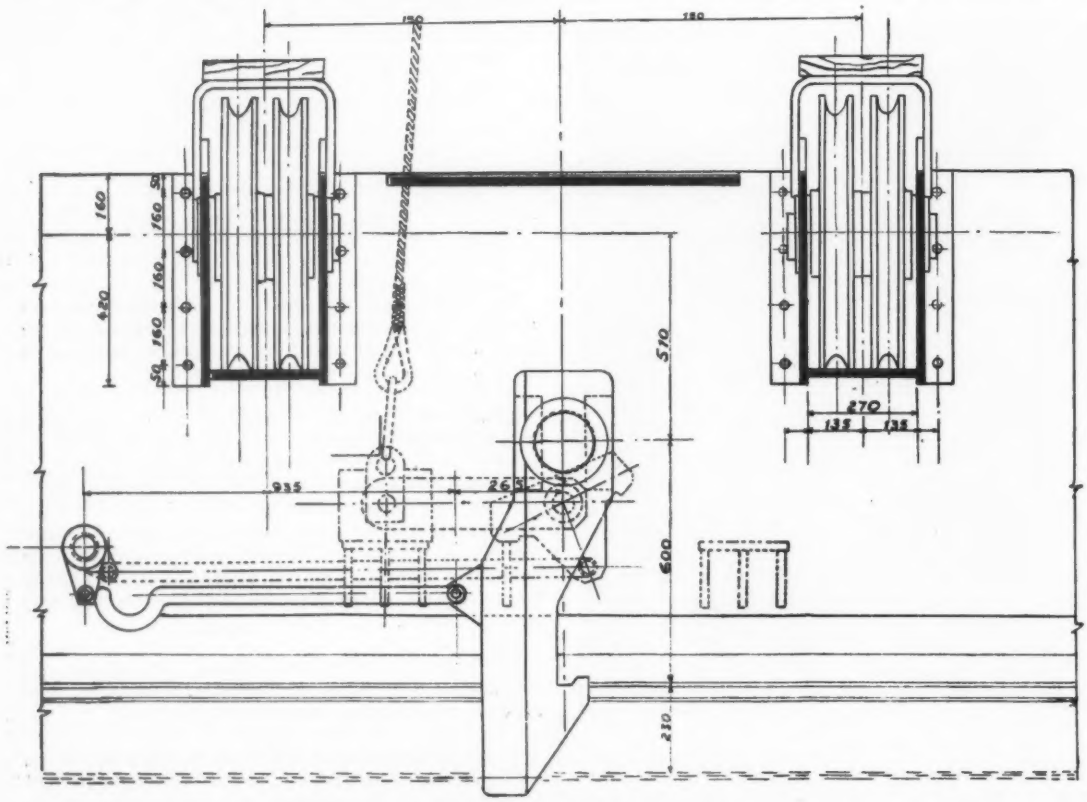
The most ticklish problem in the whole gate erection has been the fixing of seals. All the seals for the lower leaf were fitted in the yard but for the top leaf they had to be fitted after jointing it to the lower leaf. The seal at the sill level consisted of a flat rubber fitted to the bottom of the gate by a steel flat. Counter-sunk bolts were used to fix the seal and the flat to the main gate. The rubber used was of a flexible type so that it could spread under the load of the gate and make the bottom water-tight.

Directly under the gate the seal beam consisted of a thick steel flat across the sluice enabling it to take the load of the gate (*Fig. XII A*).

The side seals consisted of harder rubber. The shape of this seal was as shown in figure *XII B* and these were also fixed to the gate with a steel flat and counter-sunk bolts. The seal is pressed against the vertical steel guides due to water pressure.

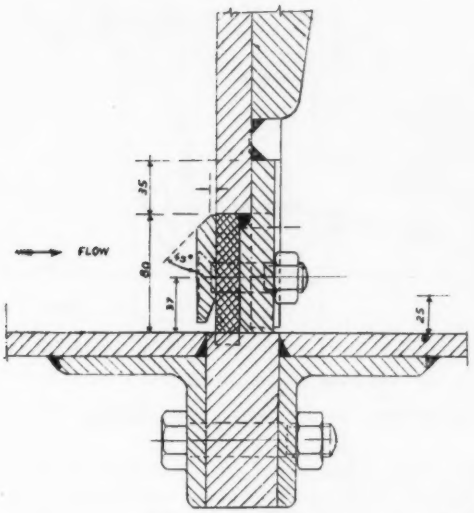
A rubber seal as shown in figure *IX* has been provided between the two leaves. It is fixed to the lower leaf with a steel flat and counter-sunk bolts. The adjustment is such that, when the top leaf is left alone part of the weight is carried by the seal and the joint becomes water tight.

The top seal of the gate consists of a rubber flat with a knob as shown in figure *XII C*. Space has been left

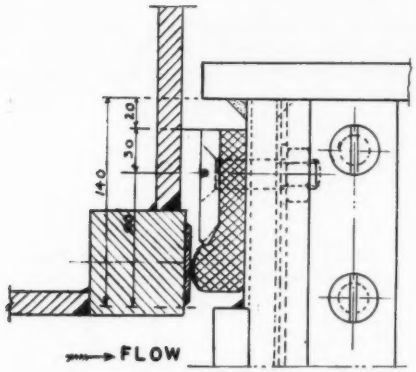


LIFTING BEAM ,HOOK, LEVER SECTION

FIG. VIIC.



BOTTOM SEAL. FIG. XII A.



SIDE SEAL FIG. XII B.

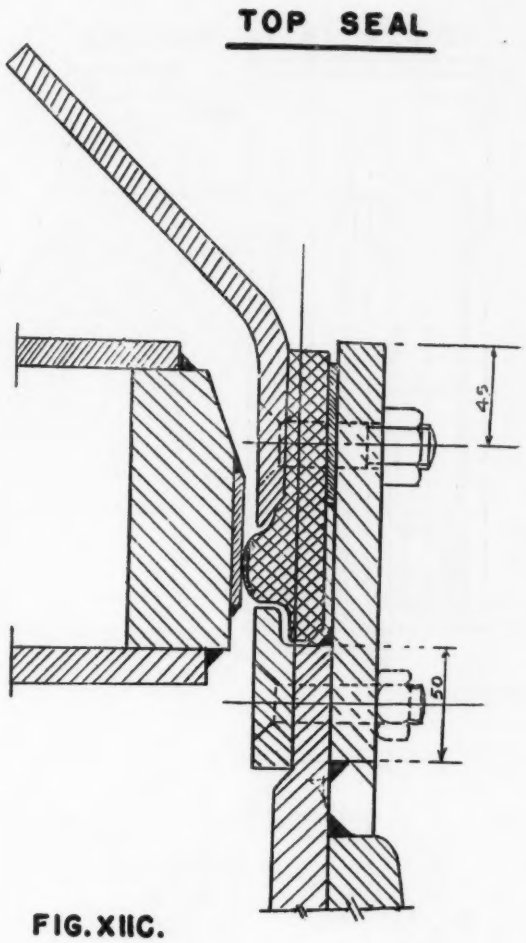


FIG. XIIC.

behind the rubber for water to enter and press it against the embedded steel part at top. It is protected from top by a bent plate. A stainless steel strip is moulded into the rubber seal to come in direct contact with steel surface of guides and avoid damage to the seal.

Painting

All metalwork that was to be exposed was sand blasted and painted in shops with one coat of read lead. In the field all the exposed embedded parts were painted after actual erection and grouting. The surfaces were properly cleaned with wire brushes and rags. Where necessary, the dirty surfaces were washed with jets of water and then dried with air jets before painting.

As a trial, two paints (*a*) Bituminous Shalimastic paint and (*b*) Mertol coal tar paint were tried on test pieces as also on some embedded parts. Floods were passed during the monsoon of 1955 and afterwards behaviour of water was watched. As Shalimastic paint behaved better all metal work was painted with three coats of this paint.

The gate leaves, after fitting with rollers were painted with one coat of Shalimastic paint in the yard. The other two coats were applied after erection.

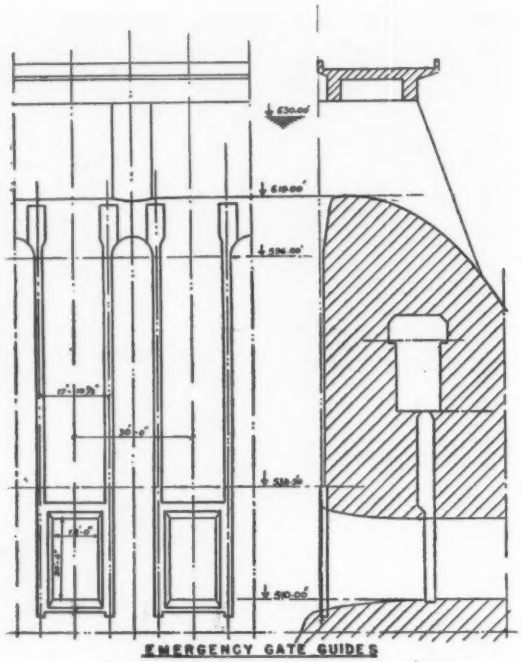
The Cranes have been painted in like manner with light grey paint to match with the gallery faces. The lifting beams have been painted black to avoid marks of grease.

Emergency Gate Guides

The full height of emergency gate guides and armature from EL. 507.0 to EL. 610.0, approximately 103 feet was fabricated and received in 7 sections(*Fig. XIII*)

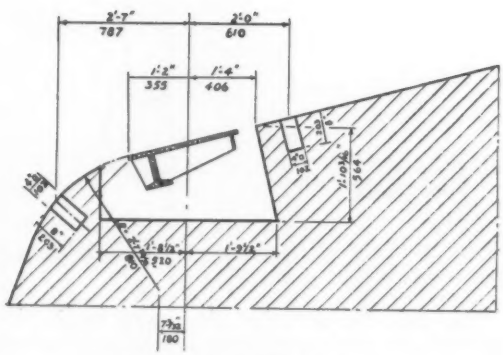
(*a*) The sill beam consisted of a plate with a central zinc sprayed strip and rails at the bottom. When erected with a crawler crane in the blockout left for the purpose and aligned, it became flush with the bottom slope of sluice bell mouth (*Fig. XIV*). Anchor rods were left in the blockout while concreting and they were rigidly attached to this beam.

(*b*) Side guides from EL. 507 to EL. 536 also with vertical zinc sprayed strips. The side guides were



EMERGENCY GATE GUIDES

FIG. XIII.

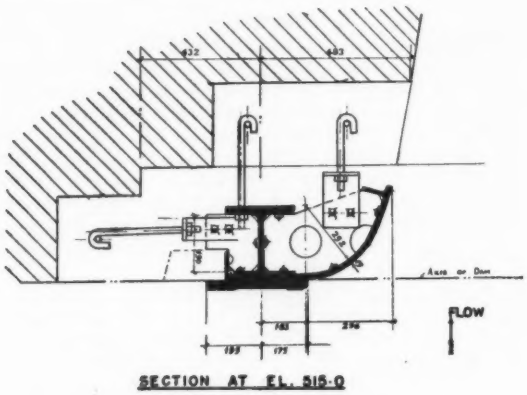


EMERGENCY GATE SILL FIG. XIV.

provided with projections at the bottom and top. At the bottom they had projection of the same section as that of the sill beam and were jointed to it with counter-sunk bolts. At EL. 534, top of the sluice bell mouth, they had projection of the section of top horizontal member to which they were bolted with counter-sunk bolts (*Fig. XV*).

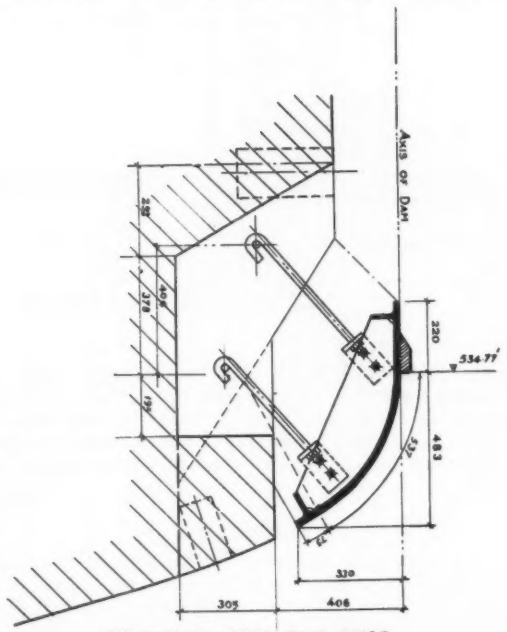
They were also handled and erected wth a crawler crane and anchored onto the rods left in the blockouts. In addition, special platforms were made by trestle so that workmen could stand at different leavels and handle the guides during erection and plumbing.

(*c*) The top horizontal member at EL. 534 was of the same section as the bell mouth curve of the sluice. It was hoisted in place, anchored on to the blockout rods and bolted to the side guides (*Fig. XVI*).



EMERGENCY GATE SIDE GUIDE FIG. XV.

This whole structure was then aligned, levelled and checked for plump. Fine piano wire was used for plumbing. After adjustment the parts were held in place by frames made for this purpose. Holes for bolts were left near either side of the vertical guides; bolts were inserted in these and grouted. A frame consisting of two angles welded at the correct angle was bolted on. Wedges were then driven for final adjustment. Plank shutters were then put and concreting of the blockouts completed. This angle frame did not permit any movement during concreting.



EMERGENCY GATE TOP GUIDE

FIG. XVI.

(*d*) The armatures from EL. 534 to 600.0 came in three lengths of rails of various sections with hooks attached to the bottom flat to be bolted on to the blockout rods. Upto EL. 557.0 these were hoisted and erected with a 70 ft. boom crane. Straight angles bolted to either side of the rails with wedges were used for adjustment, plumbing and grouting (*Figs.*

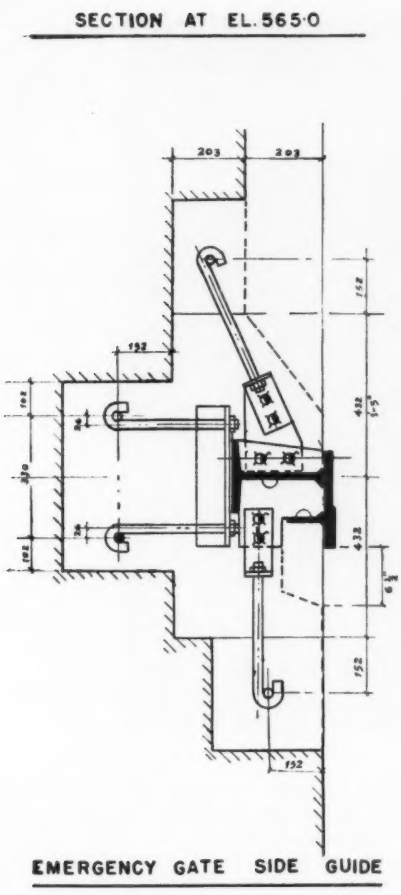


FIG. XVII A.

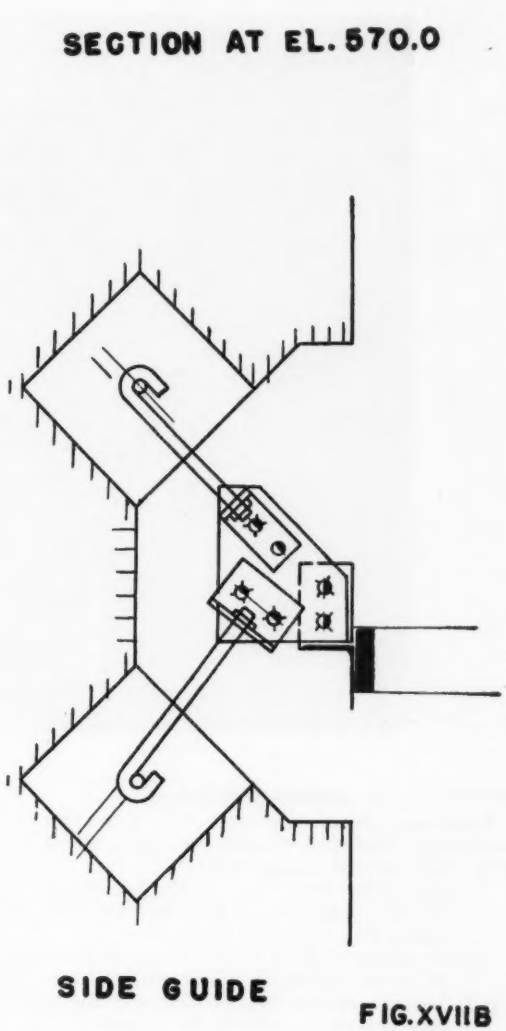


FIG. XVII B

XVII A & *XVII B*). Two pieces of rails from EL. 557 to 602 were hoisted and erected with a level Luffing crane travelling on a trestle bridge at an EL. of 557.0 on the downstream slope of the Spillway during the next season.

(*e*) The top part of the armature came in the shape of pigear. This was necessary to catch the hooks of the emergency gate when water level is above EL. 610.0. The pigears confronted to the upstream slope and curve of the Ogee. Hosting, erection, adjustments and grouting was done in the same manner as that of the armature rails.

For the purposes of concreting pipes were let down from the crest with hose at the bottom and funnel at top. Very flowy concrete was mixed on the crest and poured in and vibrated into the blockouts.

100 Ton Gantry Crane and Emergency Gate Leaves

One 100 ton gantry crane will be erected on the bridge of each spillway. Rails have been provided directly above the beams of the bridge for this purpose.

Emergency gate leaves have been received in four pieces. Rollers have been fitted to each part in the yard and the gates will be assembled after erection of the cranes. Two leaves have been provided for either spillway and the storage structure for these leaves have been provided almost in the centre of the transition blocks.

Crest Gates

To control the water above EL.610.0 and to hold it upto EL. 630.0 radial gates have been provided in the Spillways — 21 Nos. 51 ft long 20 ft. high on the Left Spillway and 13 Nos. of the same size on the crest of Right Spillway (*Fig. XVIII*).

For this span and this depth of water tainter gates are the most suitable type and the choice was obvious.

Due to delay in the supplies of these gates parts the bridge had to be completed before erection of crest gates and this naturally has resulted in more difficult erection methods.

The gates are being fabricated and received in four major groups.

(*a*) Anchorage girders.
(*b*) Sill beams and side guides
(*c*) Bearings, arms and gates
(*d*) Hoisting gear

Anchorage Girders

Anchorage girders were received in time and erected before concreting of piers was taken above EL. 615.0 These girders consisted of:

(*i*) main girder 10′5″ c to c of the bearings placed on the downstream of the pier parallel to the axis at EL. 618.0, 28′ from axis.

(*ii*) Six channels 10″×5″ placed on the pier parallel to the axis at EL. 615.0 and 9′6″ from axis.

(*iii*) The six anchor rods to transmit the thrust from the main girder to the channels.

Each rod 4″ diameter had four angles welded on at one end and threaded at the other. Two channels were placed on either side of two rods, placed in one plane, diverging towards the main girder and the channels and rods jointed by rivetting. These three sets were placed one above the other—all the six rods passing through the holes of the main girder. Nuts were then fastened on to the other end. Proper steel stools were provided for the channels and the anchorage girder for adjustment and concreting. Asphalted paper was wrapped round the anchor rods enabling complete and balanced transmission of trust to the channel. The anchor girder had one stool at either end to take the bearing (*Fig. XIX B*).

The alignment of levelling and adjustment of these girders was done with the greatest care as these girders form the key to the erection of the gates and their functioning. Besides, each anchor girder took one bearing of one gate and one bearing of the next gate. As such the whole length of 1251 feet was connected up. Provision of free ends of the anchor rods however will always permit adjustment.

Sill beams and Side guides

Fifty one feet long sill beam has been received in three sections of 16 feet each with two end pieces (*Fig. XX*). The end piece had 1′2″ of the sill beam and one foot of side guide and came as a corner piece.

23 feet high side guides are coming in two parts 11.5 feet each, and each one has an angle at the centre. Next piece also fits at one angle. The whole side guide has thus been made in straight line bending such that the corners of stainless steel strip lie on an arc with 20′ radius from beam. The arc of the movement of the radial gate always lies within the central 4 inches wide stainless steel strip which has been fused in the side guide metal work. The same width of stainless

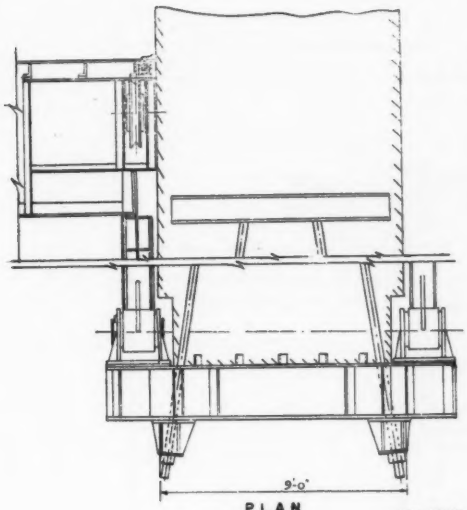
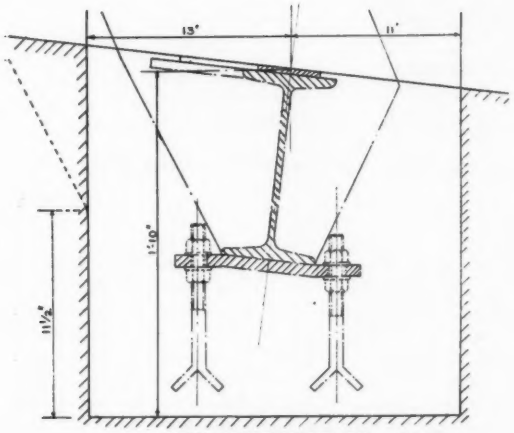
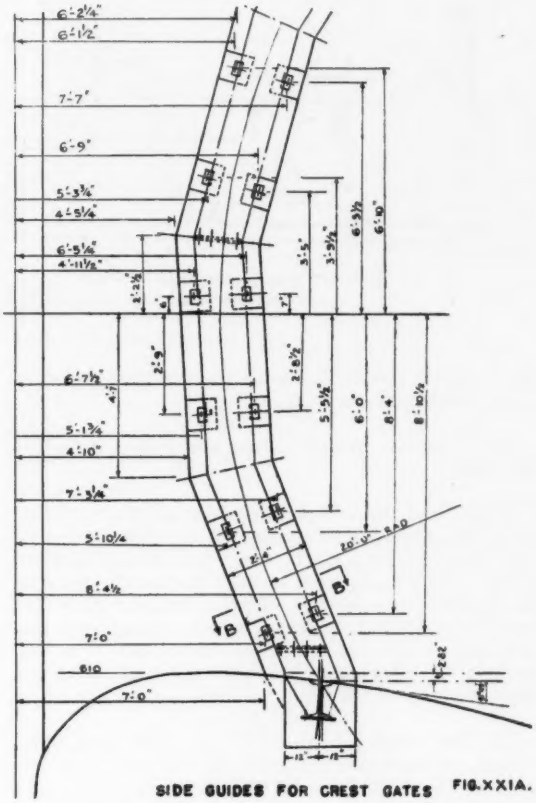


FIG. XIX B.

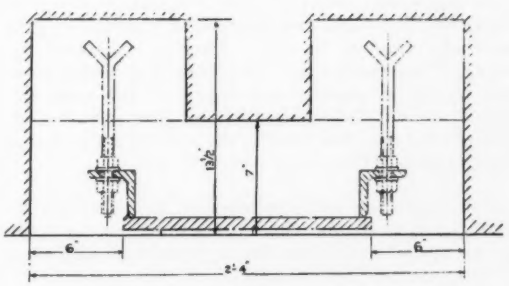
SPILLWAY RADIAL GATE
ANCHORAGE GIRDER & HOISTING ARRANGEMENTS.



RADIAL GATE BLOCKOUT FOR SILL BEAM FIG. XX.



SIDE GUIDES FOR CREST GATES FIG. XXIA.



CREST GATE – SECTION THROUGH SIDE GUIDES.

FIG. XXIB.

steel strip has been fused in the sill beams and end pieces (*Figs. XXI* and *XXI B*).

The sill beams and side guides are lowered with a mobile crane onto the crest through the 6 feet × 3 feet man-hole left in bridge slab over each per. The sill beam and end pieces are then placed in the blockout left for the purpose, aligned, levelled and grouted. Side guides are then erected and grouted.

Gates

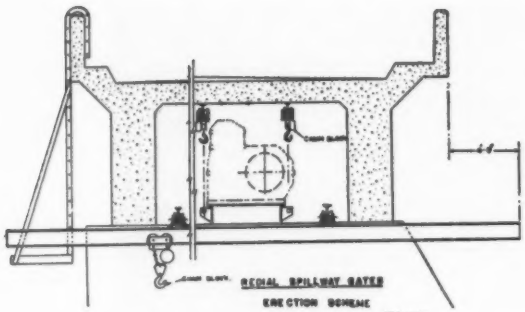
Due to the completion of the bridge, special erection tackle had to be designed and made for erection of the gate. This tackle has been made for three spans and consists of two long girders, spanning from pier to pier and resting on the piers. The girders are placed just inside the bridge beams and are supported from the slab for rigidity.

Two cross girders are mounted on the bottom flanges of these girders by a set of rollers facilitating movement in any desired place in the span.

One 5 ton traversing chain pulley block is mounted on the lower flange of each cross girder (*Fig. XXII*).

For the purpose of handling the heavy gate parts a 52 ton crawler crane had to be taken on the bridge. As the bridge slab is designed for only class A loading, the load of this crane has been transmitted to the beams by keeping girders across the bridge on sleepers supported directly by the beams.

The bearings are first suspended by the crane on the downstream of the bridge. These are transferred to



chain pulley blocks, taken to the anchorage girders and bolted in place.

By a similar method arms are bolted onto the bearings.

Erection of the two main girders and their bolting to the arms is the most dangerous and difficult operation. Each girder is 50′11¼″ long, 5′ wide built in plate girder, weighing 6½ tons. Besides, the two have to be fixed to the arms at two different angles. After the arms are raised to the proper position, so that when the skin plates are erected a gap of at least 6″ is left between the sill beam and the skin plate; the arms are supported by sleeper and packed.

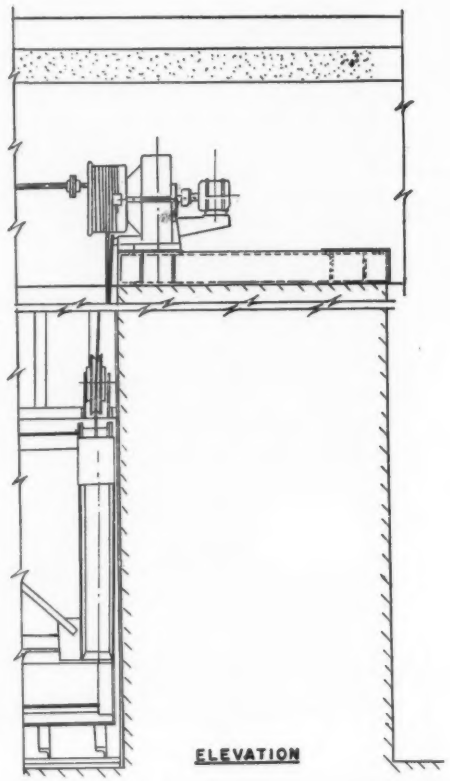
The two cross girders of the erection tackle are moved in position—approximately 15 feet from the pier. The lower girder is then brought in and suspended on the upstream of the bridge, separate slings are fixed to these girders outside for transfer to chain blocks. These slings are of different lengths and are so arranged that when the load is transferred to the blocks the girder assumes an angle at which the girder has to be fixed to the arm. After it is lowered far enough it is transferred to both the pulley blocks. It is then moved in position and bolted on the arms and supported and packed by sleepers. Similarly the top girder is lowered and fixed to the arm. After levelling the two girders braces are put in.

Skin plates are being received in nine sections 20′ high curved to shape. These are lowered by the crane on the upstream, handled by a chain block and fixed to the girders (*Fig. XXIII*).

Hoisting gear and shaft

Hoisting gear consists of two gear boxes,one at either end of the span, housed on the pier under the slab just inside the downstream beam. The two gear boxes are connected by a shaft which is being received in pieces. The shaft is supported from the slab at three places. At supports, bearings have been provided. A 4-horse power motor is mounted on one side only and operates both the gear boxes, through the shaft. Gear boxes have rope drums on the span sides. One gear box for one gate and the other with the motor for the next gate are mounted on the same base plate. The base plate is lowered on to the pier by the crane (*Fig. XXIV*).

Two small girders are bolted on the lower side of the bridge deck. Two ton traversing pulley blocks are mounted on the lower flange of these girders. The



SPILLWAY RADIAL GATE HOISTING ARRANGEMENTS.

FIG. XXIV.

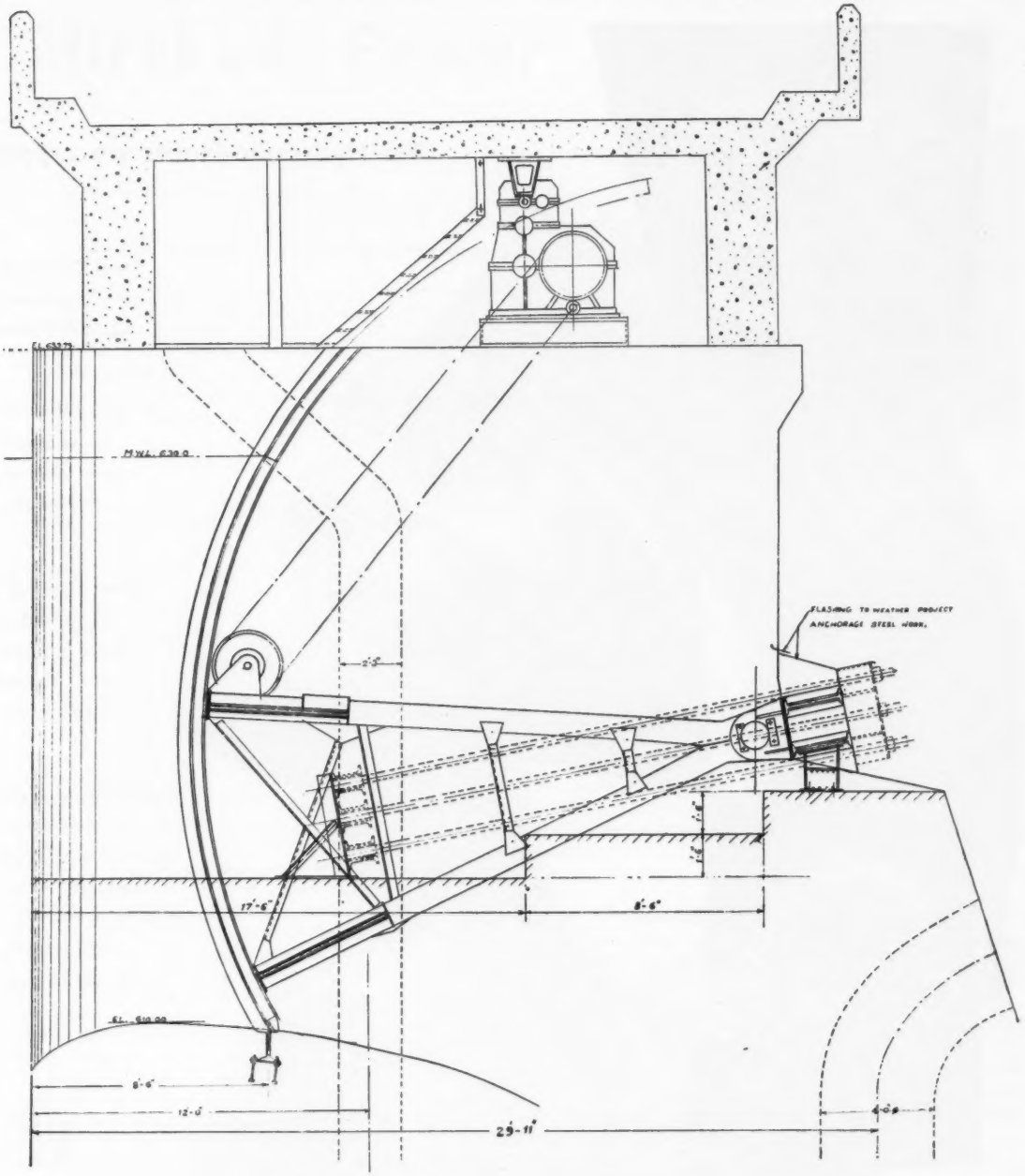
base plate is handled by these blocks and taken in position, adjusted and grouted. The two gear boxes for each pier are then lowered one by one on the downstream of the bridge. It is taken in by the pulley block on the cross girder and then transferred to the two 2-ton pulley blocks, taken in position and bolted to the base plate. Each gear box is connected to one end of the gate by a wire rope 1 3/8″ diameter.

After thus completing a gate the girders on the bridge are moved on to the next span to erect the next gate.

Rivetting

Five inches wide strips are provided on both sides to cover the butt joint of the skin plates. These strips are taken down and bolted on to the skin plates. Bolts are provided in the alternate holes.

Rivetting is then started. The furnace is taken on the girders of the gate and rivetts are being heated there. On the upstream face of the gate platforms supported on angle frames bolted to the gates have been made for rivetters to stand. These angle frames are collapsible and so designed that by slight adjustment they support a horizontal platform at any elevation. Rivetting is being done with pneumatic hammers and pneumatic dollys are being used. Each rivett is tested after cooling and the undesirable ones removed. The alternate holes left blank are first rivetted and then bolts are removed from the rest of the holes and rivett ing completed.



RADIAL GATE ON SPILLWAY CREST. FIG. XXIII.

Seals

The rubber seals being used are wide and flexible. They are being fixed to the skin plates with steel flat and bolts. The corner pieces of the seals have been specially made to avoid leakage. The seals move smoothly over the stainless steel guides.

Painting

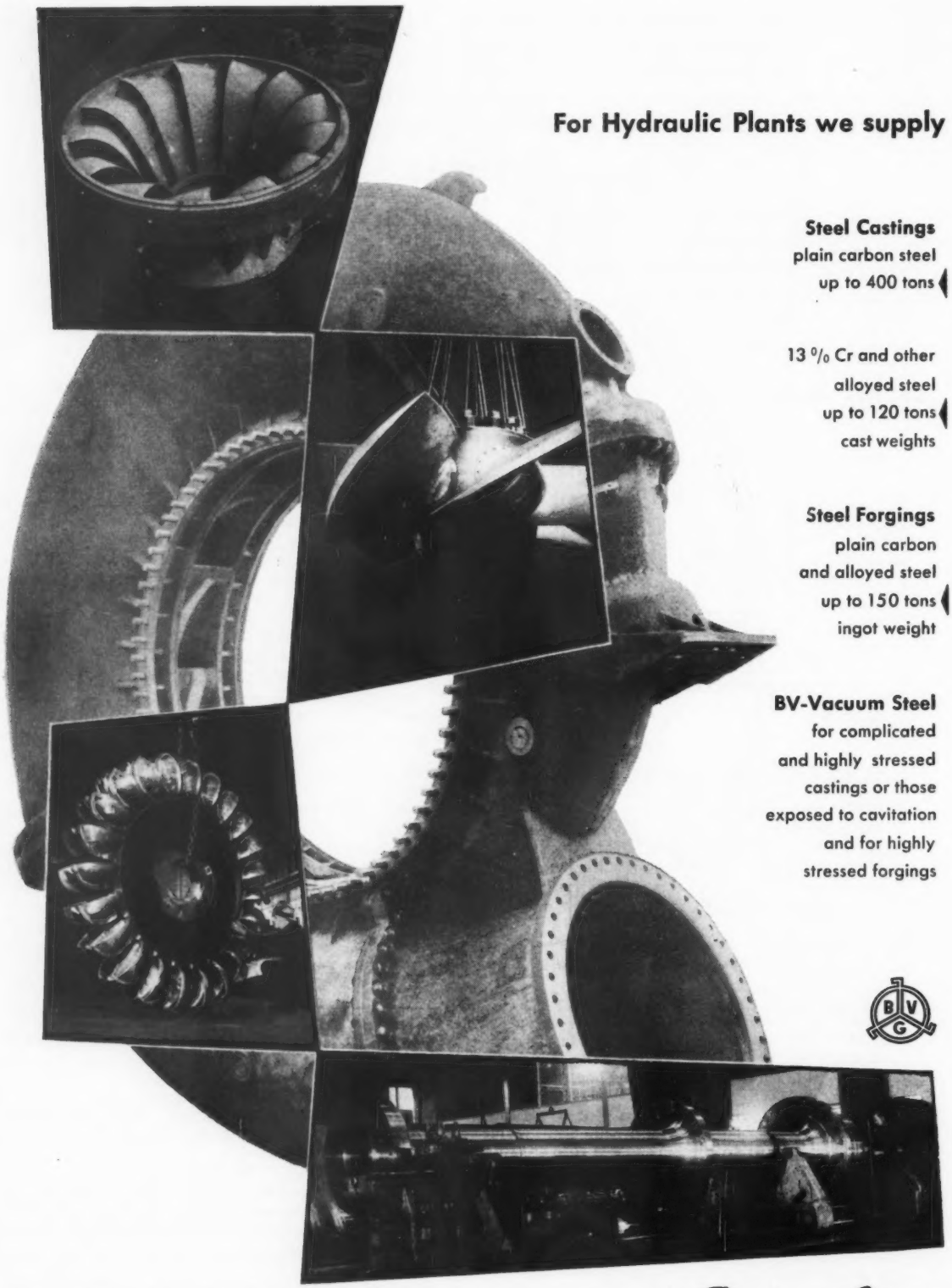
The shop paint consisted of one coat of red lead after proper cleaning by wire brushes.

In the field after completion of a gate and its hoist mechanism another coat of red lead is being applied on the anchorage girders and gates while one coat of battleship grey is being applied on the hoist mechanism.

Hoisting

The hoisting speed is 1 foot per minute. After every foot opening an automatic cut out comes into play and the gate stops there. It has to be switched on again for further opening.

In addition to electrical operation, mechanism for manual operation of the gate has also been provided.



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Hirakud Power House

By

Dr. K. C. THOMAS, B.Sc. (Eng)., M.S., D.Sc. (Eng)., A.M.I.E. J.M.ASCE, M.ACI, M.SICF.

Executive Engineer, Power Dam Division Hirakud Dam Project

AUTHOR

In an earlier contribution, the Hirakud Power System has been described. In the present contribution a description of the Hirakud Power House and associated works is included. The principles underlying the design features of the Power House and its component units have been briefly discussed. The article ends with a short note on the future expansion of the generating capacity as well as of the second power house proposed to be erected at Cliplima a few miles down the tailrace.

Mahanadi is one of those large rivers in India, and the largest in Orissa, whose uncontrolled flow has been going to waste into the sea, causing enormous damage to the lands and property on its way. This mighty river draining an area of 51,000 sq. miles and having an average annual run-off of 74 million acre ft., runs through the heart of Orissa for over 300 miles. Above the Hirakud Dam site, the river has a water-shed area of 32,200 sq, miles and the average annual run-off at the Dam site is of the order of 50 million acre ft. This is made up of a dry weather flow dwindling down to 100 or 200 cusecs and flood discharge rising as high as a million cusecs. The three mile long Main Dam plus the 13 miles of Dykes of the Hirakud project has created a reservoir, which has a gross capacity of 6.6 million acre ft. at the full reservoir level of R.L. 630. Leaving a dead storage capacity of 1.88 million acre ft. upto RL 590, the reservoir has a live capacity of 4.72 million acre ft. Using this enormous capacity, it will be possible to control the floods and limit the flood discharges below the Dam to a maximum of 7,00,000 cusecs in normal years, and in addition, utilise about 10.5 million acre ft. of water for providing perennial irrigation and cheap hydro electric power to change the face of Orissa to a land of plenty and industrial advancement, free from flood ravages. Out of the 10.5 million acre ft., about 7.5 million acre ft shall be used for power generation. Utilising the 90 ft. average head obtained at the Hirakud Main Dam and another 75 feet fall in the river bed in the 17 miles reach immediately below the Main Dam, an ultimate generation of about 2,00,000 k.W. of firm power is envisaged. This will cater to most of the needs of the State of Orissa and parts of Bihar and Madhya Pradesh, making it possible to successfully exploit the abundance of mineral wealth and other natural resources of this area.

General description of the first stage works

The river at the Dam site consists of two outer main channels and a smaller middle channel with islands in between. The right channel is closed by a 2,128 ft. long concrete-cum-rubble masonry straight gravity Dam abutting on the hill at the right end and junctioning with the middle Earth Dam at the Island end (fig. 1). Out of this 2,128 ft., the Left section forms a concrete Spillway and the balance 950 ft. built in rubble masonry, forms the Power Dam plus the Transition blocks abutting on the hill. In the Power Dam blocks are provided seven numbers of main penstocks, 5 of them 25 ft. in diameter and two 23 feet in diameter. In the first stage, two 25 feet diameter penstocks will feed generating units each of 37,500 k.W. capacity and two 23 ft. diameter penstocks will feed generating units each of 24,000 k.W. capacity. There is also a smaller 3 ft. diameter penstock provided to feed a 450 k.W. House Service Unit. These four main units and the House Service unit are now being installed in the main Power House immediately down-stream of the Power Dam blocks and constitute the first stage installations for power development. The remaining three penstocks are for the installation of future units in the subsequent stages.

Selection of first stage Generating units

The generally accepted basis for comparison of the characteristics of hydraulic turbines is the specific speed, Ns, which is the speed in revolutions per minute at which a turbine of homologous design would operate, if the runner were reduced to a size which would develop one horse power under one foot head. The specific speed varies directly with the speed of the turbine (N in r.p.m.), the square root of its horse power (P), and inversely with the five quarters power of the head (H).

i.e. $$N_s :: \frac{N\ P^{1/2}}{H^{5/4}}$$

The higher the specific speed for a given head and horse power output, the smaller the size of the turbine and generator (See fig. 2).

The reduction in the weight and cost of the generator is in a greater proportion than the corresponding items for the turbine. This reduction in the weight of parts to be handled by the Power House cranes reduces the cost of the crane, station superstructure and foundation. In short, there will be an overall reduction in the cost of the installations. In actual practice, however, there are certain limitations on the use of high specific speed machines. A very high running speed of the machine will involve dispro-

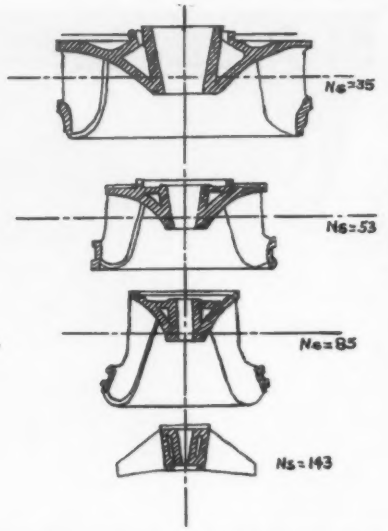


FIG. 2.. COMPARITIVE SIZE OF RUNNERS OF EQUAL POWER BUT DIFFERENT SPECIFIC SPEEDS.

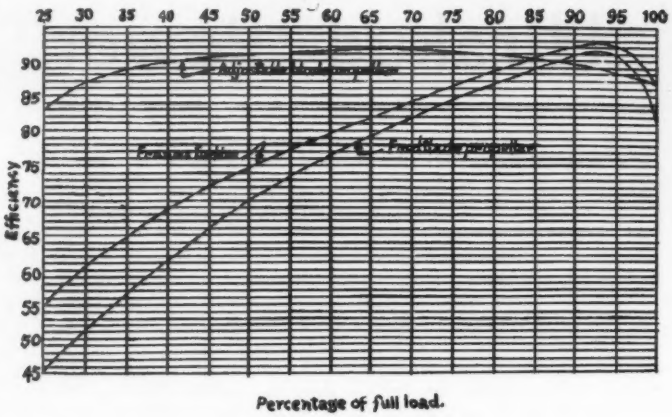
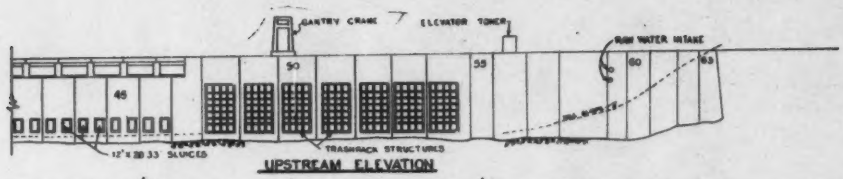


FIG. 3.... EFFICIENCY CHARACTORISTIC OF DIFFERENT TYPES OF REACTION TURBINES.

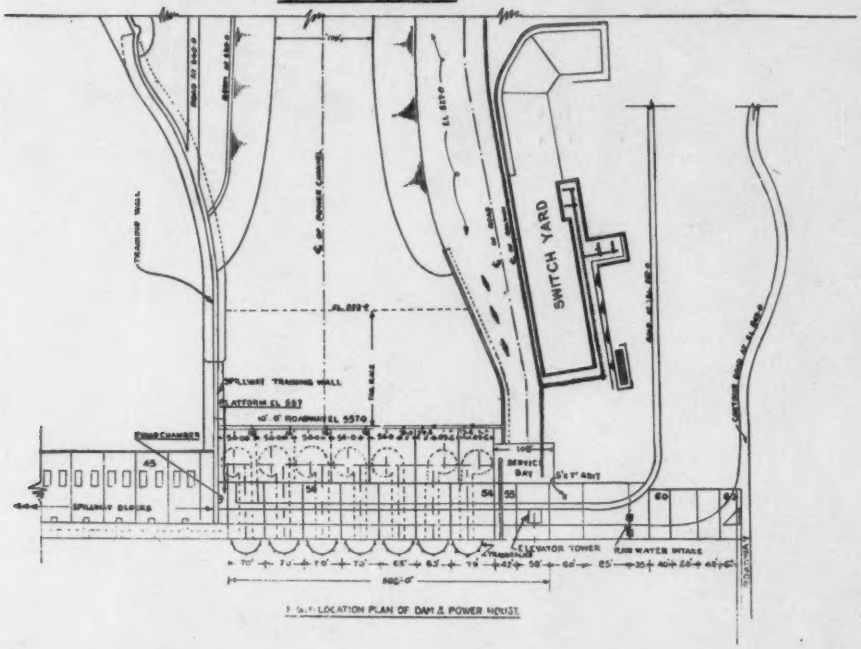
portionately high cost, on account of the extra strength required in all the component parts. In other words the range of allowable running speed being limited, a high specific speed design is suitable for relatively low heads and lower specific speed design, for higher heads. Francis type reaction turbines have relatively low specific speed and are normally adopted for heads from 100 to 1,000 ft. There are, of course, instances of its use for lower heads and also for very much higher heads. However, modern practice is to adopt the higher specific speed, propeller type turbines for heads upto 100 or 125 feet. The higher speed causes a slight reduction in efficiency at full load and considerable reduction at part load, if the blades are of the fixed type (see fig. 3). But in adjustable blade propeller turbines (Kaplan type), in which the blade angle is automatically adjusted with load changes, a high efficiency is obtained over most of the range. Even with the adjustable-blade propeller design, the specific speed had to be limited. Otherwise, the turbine is reduced to such a size that the discharge velocity of the water into the throat of the draft tube would become relatively high, tending to create sub-atmospheric pressures and serious cavitation may develop. The relative velocities between the blades and water also become dangerously high. These tendencies are counteracted, to some extent, by installing the turbines a good depth below minimum tail water level, assuring a positive pressure on the blade and draft tube throat ; but a lower setting of the turbine correspondingly lowers the bottom of the draft tube necessitating deeper foundation excavation.

Fixed blade propellers are cheaper than Kaplan type turbines and they would be preferred where the load and the head on the machines are fairly constant ; as under these conditions, they will be running at or near the point of best efficiency. Movable blade machines will be preferred when frequent part load operation of the unit is necessary. On this consideration it will not, however, be necessary to have more than two movable blade units in a multiple unit Power House and the remainder could be fixed blade type. But where there is a large variation in the operating head and sustained capacity is desired to be maintained even at low heads, it would probably be desirable that all units even in a multiple unit Power House be of the movable blade type.

The multipurpose utilisation of the Hirakud reservoir puts conflicting demands on water storage. The commitment for perennial irrigation to a vast area and supply of firm power to industrial establishments require the water to be stored and the reservoir kept full, whereas the enormous absorption capacity required to control the Mahanadi floods demand the rservoir to be depleted and kept empty during the monsoons. The irrigation canals take off at about RL 580 and the minimum reservoir level is fixed at RL 590. Providing for a live stage capacity of 4.72 million acre ft. the full reservoir level is fixed at RL 630. This amounts to a fluctuation of 40 feet over the average head of about 90 ft. obtained at this Power station. The anticipated power load on the Hirakud system is mostly industrial, with a high load factor and is sustained throughout the year. Based on all these factors, it was originally decided to have all machines in the Hirakud Power House to be of the adjustable blade propeller type, and all to be of the same capacity of 37,500 k.W. This decision was, however, coupled with the scheme for power generation at a subsidiary Power House at Chiplima by taking a power channel in contour and utilising the 75 to 80 feet drop in bed level of the river in the seventeen mile reach between Hirakud and Chiplima. The proposal was to complete this second Power House about two years earlier than the main Power House and commission it by utilising the storage capacity obtained in the main reservoir by the partial completion of the Main Dam. Orders were placed on M/s. Voith, Germany, for two Kaplan type units of 24,000 k.Ws. to be installed in the subsidiary Power House. However, due to certain policy decisions, the Government of India, in December, 1951, ordered the immediate suspension of all works on the subsidiary Power scheme. No indication as to whether and when this work will be resumed was given. It was, therefore decided to utilise, in the main Power House, the two generating units ordered for the subsidiary Power House. The average head for the second Power House was about 75 feet with a very small range of



UPSTREAM ELEVATION



LOCATION PLAN OF DAM & POWER HOUSE

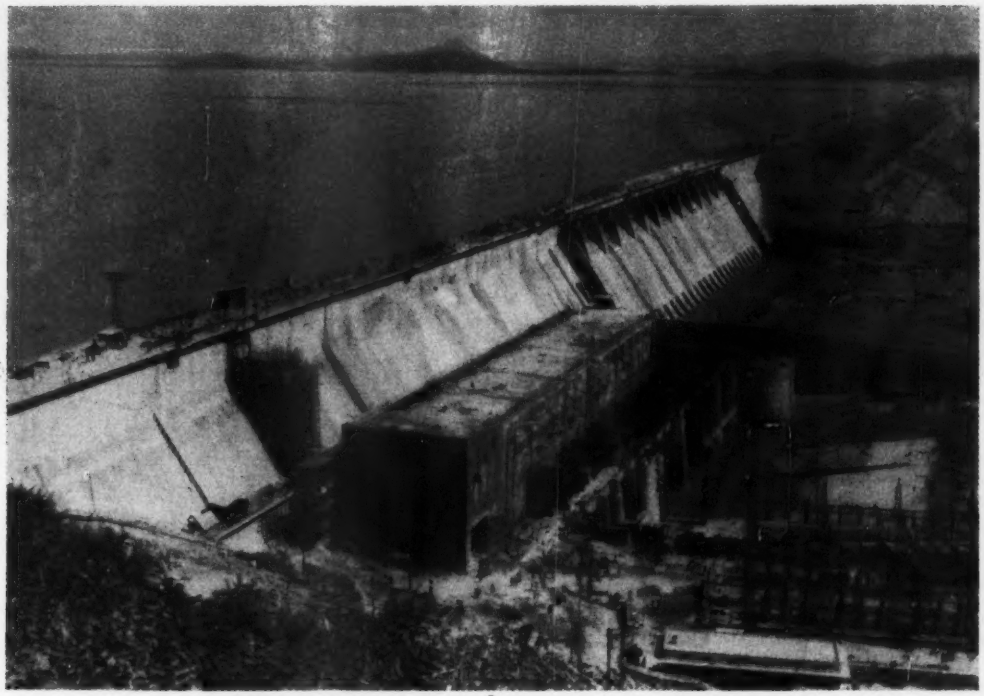


Plate 1—View of Right Channel Dam and Reservoir with Power House in foreground

fluctuations, whereas on the main Power House, the head varies from about 75 to 115 feet. It as recognised that a turbine designed for the lower head condition at second Power House cannot be installed in the main Power House with the very much greater head. The manufacturers were, therefore, approached and they undertook to design and supply a new turbine which will be suitable, under the main Power House condition to be coupled to the generator originally designed for the second Power House. Naturally they had to choose a runner with lower specific speed and they have designed and supplied a Francis type runner. All other items including the generator, scroll case, Draft tube steel liners and penstock liner meant for the second Power House have been utilised in the main Power House. This has necessitated a deviation from the original proposal of the Main Power House having all units of Kaplan type and of the same capacity. The actual first stage installations have thus become two English Electric Kaplan type turbines of 37,500 k.W. output and two Voith, German Francis type turbines of 24,000 k.W. output. The direction of rotation of these two groups of machines happened to be different—the English Electric machines rotating clockwise and the Voith machines rotating anti-clockwise. This has caused the unsymmetric disposition of the penstocks and scroll cases in the main Power House (see figs : 1 and 8). The future units are, however, proposed to be anti-clockwise rotation to avoid further unsymmetry.

37,500 kW. English Electric Units.

Penstock and trash rack

The penstock for each of the two English machines consist of a 25 feet diameter circular steel pipe embedded in the body of the Dam rising at an angle of $33\frac{1}{2}^{\circ}$ from the scroll case end towards the upstream

Plate 2— Centring for penstock transition

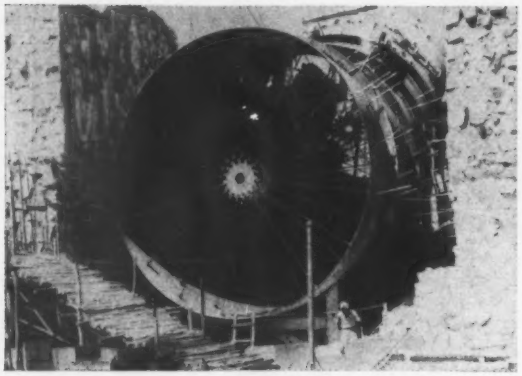


Plate 3—Penstock liner under erection.

face (see fig. 4). At the upstream end is provided a bellmouth rectangular in section. The sides, top and bottom converge through elliptical profiles to a normal rectangular cross section 19′ $7\frac{5}{8}$″ × 25′0″. From this section the penstock changes the shape with elliptical fillets to a 25 ft. diameter circle through a 28 ft. long transition section (see fig. 5). The bellmouth and transition portion is formed in concrete. For the balance length, 7/8″ thick steel liner is provided which is brought in conveniently-sized rolled sections and welded at site.

The penstock bellmouth is surrounded by a semi-circular reinforced concrete trash rack structure consisting of streamlined vertical columns and horizontal bracings (see fig. 6). In the panels formed by the columns and bracings are inserted trash racks of welded steel to prevent the entrance of logs or other large trash, which might damage the gates or turbine. These racks are purposely designed with a lower factor of safety than the concrete structure, so that in case of any inordinate thrust coming on them, the rack bars will fail first instead of the more expensive concrete structure. The top of the trash rack structure is of reinforced concrete slab and beam construction having a hatch opening for operating the stop log gate of the penstock. The top level of the trash rack structure is RL 595, i.e. 5 feet above the minimum reservoir level.

Scroll case

The scroll case is also of welded steel construction having suitable shape to create the intake vortex. The penstock liner reduces in diameter at the scroll case end to 21 feet diameter through a reducer section and is welded to the scroll case.

Plate 4—Trash rack structures under construction.

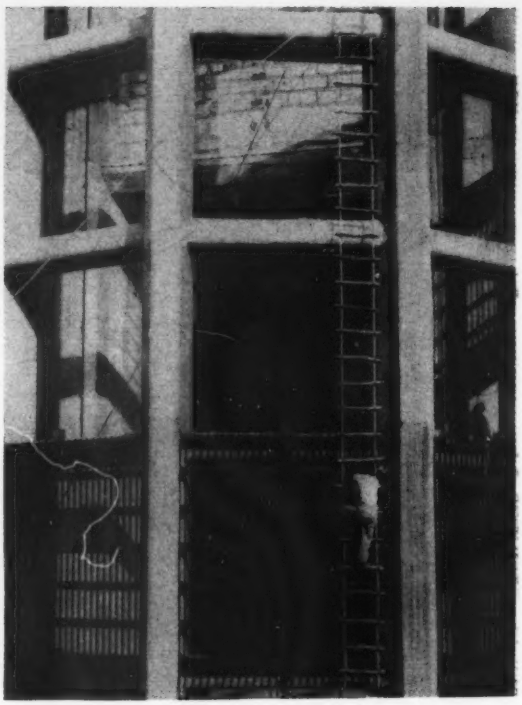


Plate 5—Trash racks being installed.

Draft tube

The draft tube provided is of the English Electric spreading bend type. Only the throat portion of the draft tube is steel lined and the rest is formed in concrete (see figs : 7 and 8). Downstream of the elbow, the draft tube is devided into two sections by a central pier. The nose of the pier is protected with plate steel nosing to prevent erosion of the concrete. Access man-hole for inspection of the draft tube is provided in the steel liner portion below the turbine runner.

Generating unit

The unit consist of a vertical shaft, single runner, movable-blade propeller type turbine directly coupled to a vertical shaft, semi-umbrella type, revolving field generator, generating 3 phase alternating current at 50 cycles and 11,000 volts and having a rated capacity of 41,664 k.V.A. at 0.9 lagging power factor. The rated capacity of the turbine is 52,000 B.H.P. at an average net head of 87 ft. with a normal speed of 150 r.p.m. Further details of the turbine are as follows :

Specific speed	..	128.5 R.P.M.
Maximum runaway speed :—		
Normal	..	330 R.P.M.
Theoretical	..	367 R.P.M.

Efficiencies at the designed net head of 87 ft. are :

(*a*) on full load	..	90 per cent.
(*b*) on three-fourth load	..	92 per cent
(*c*) on half load	..	89 per cent

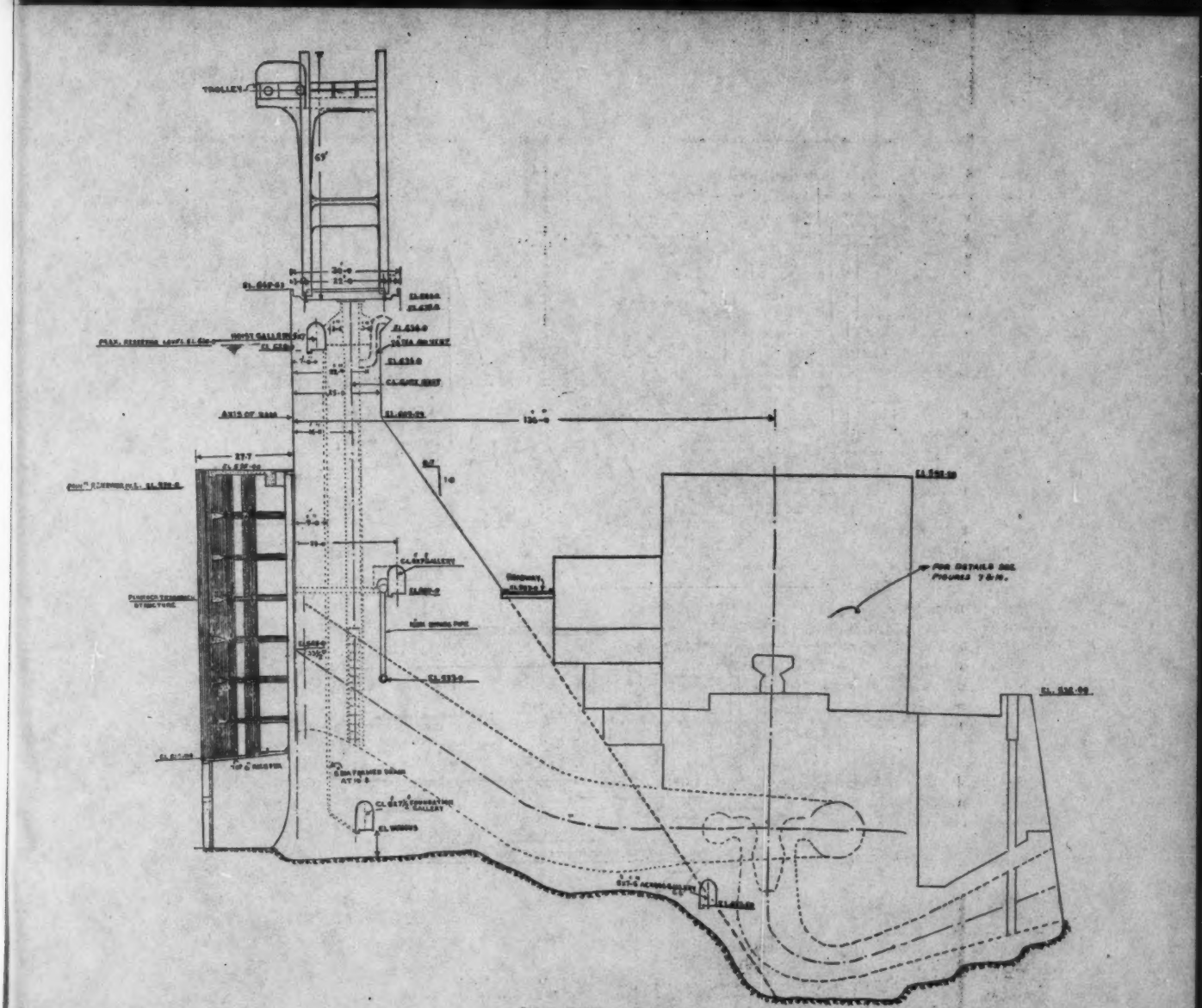


FIG. 4 - SECTION OF POWER DAM & POWER HOUSE

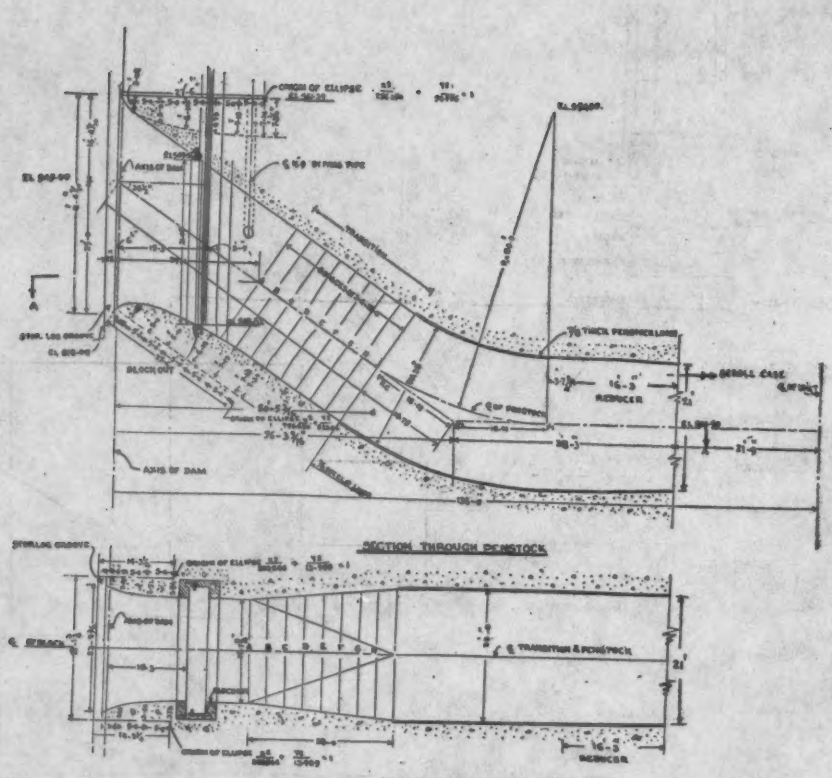


FIG. 9.- DETAILS OF PENSTOCK FOR ENGLISH UNITS

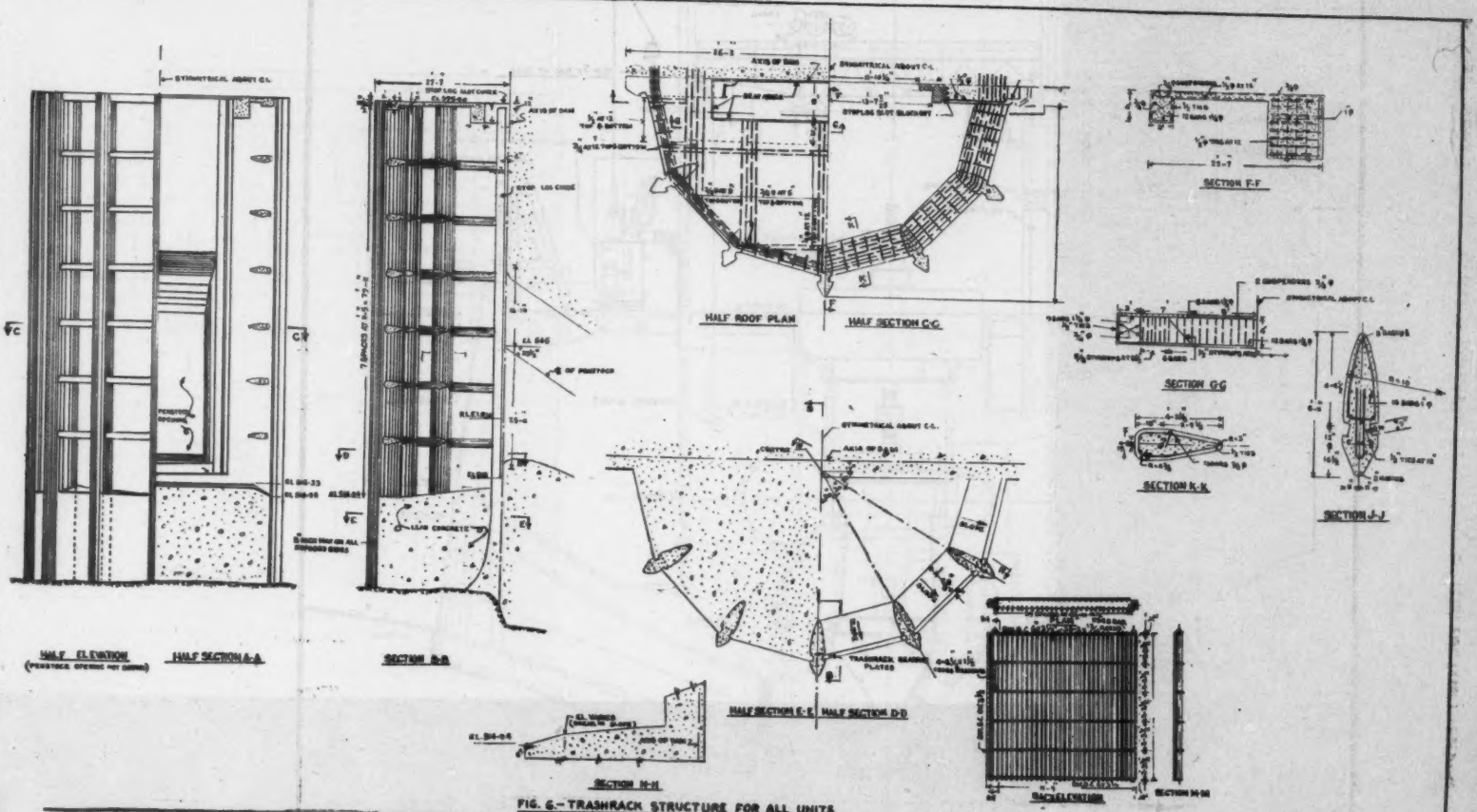


FIG. 6.- TRASHRACK STRUCTURE FOR ALL UNITS

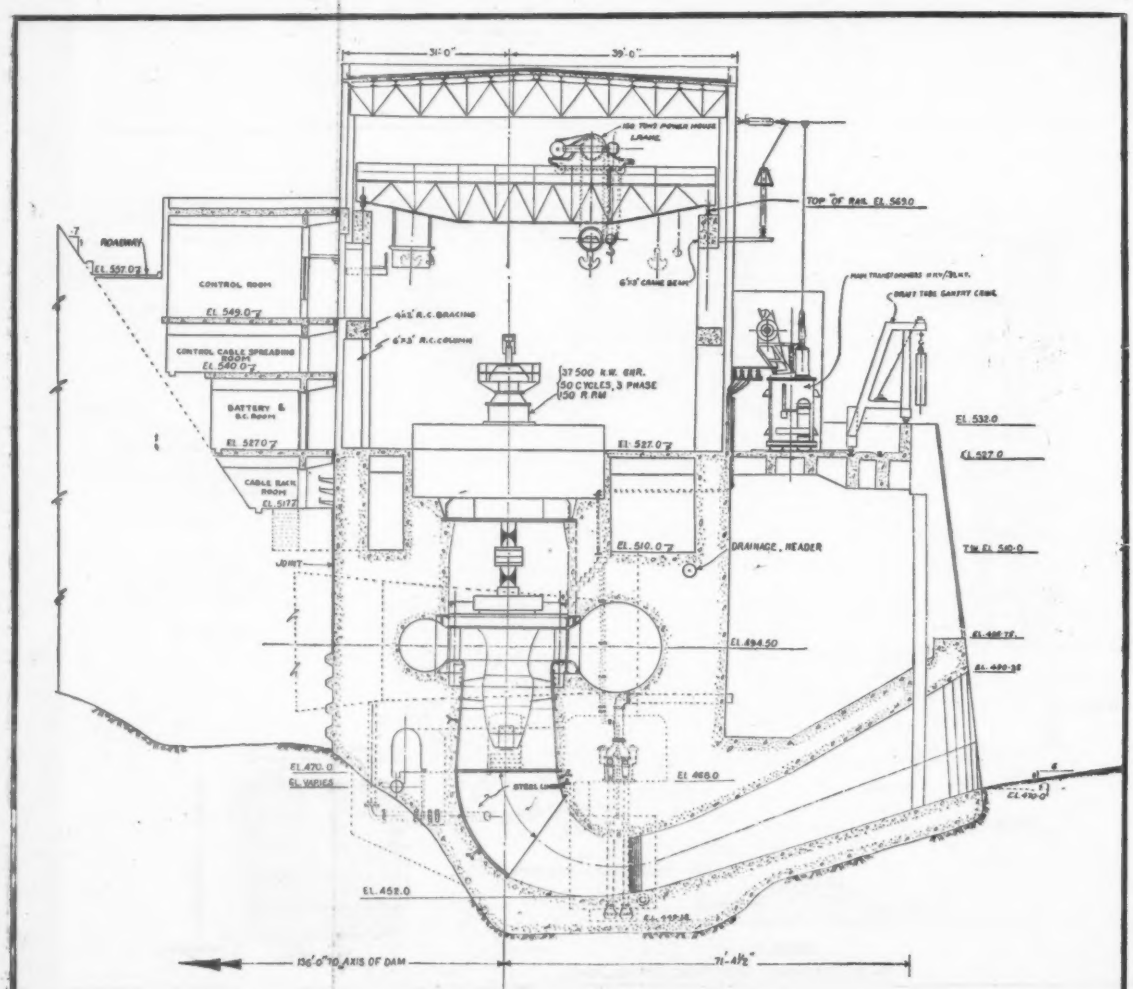


FIG. 7
CROSS SECTION THRO. ℄ OF ENGLISH UNITS

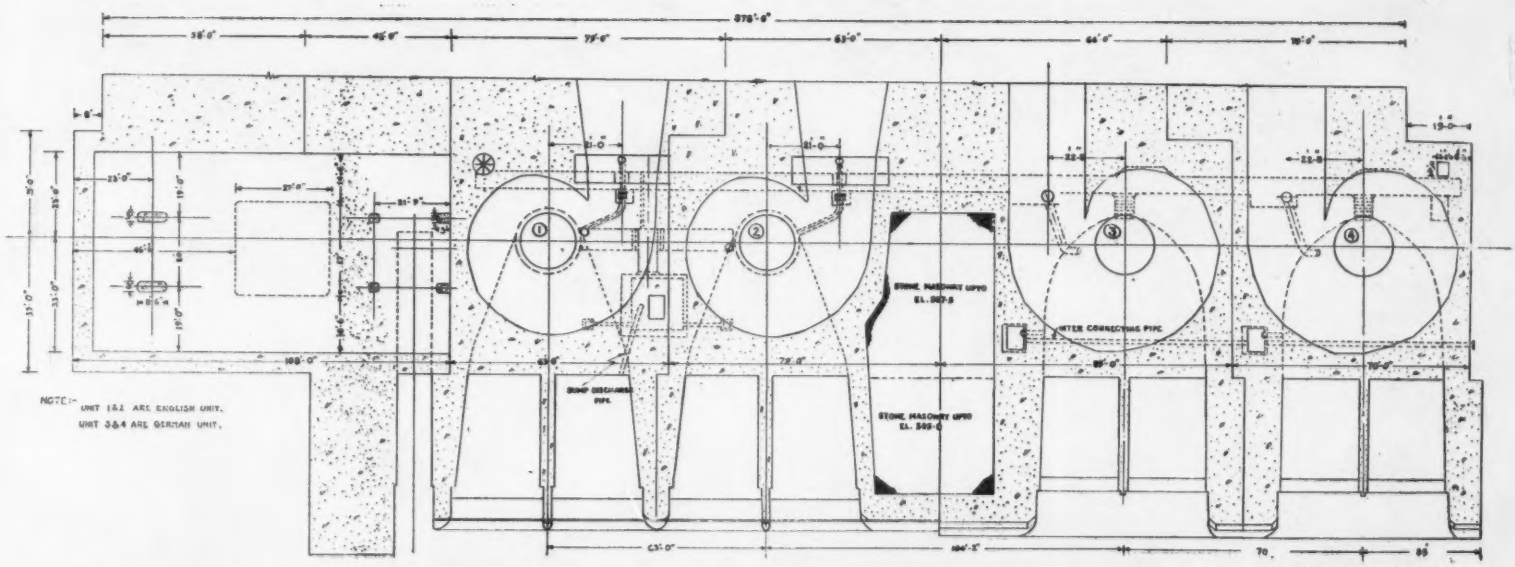

378'-0"
NOTE:- UNIT 1&2 ARE ENGLISH UNIT.
UNIT 3&4 ARE GERMAN UNIT.
STONE MASONRY UPTO EL. 867-5
INTER CONNECTING PIPE
STONE MASONRY UPTO EL. 865-0
DRAFT TUBE PIER

FIG. 8 - PLAN SHOWING DISPOSITION OF UNITS IN POWER HOUSE

Plate 6—Draft tube liner and form work for the unlined portion of draft tube.

The generators are of the semi-umbrella type with the thrust bearing below the rotor.

An automatic actuator governor of the oil pressure type with electrically driven speed responsive element of ample capacity and capable of maintaining complete control of speed under all operating conditions and within the limits specified, are provided with each turbine. The governor is highly sensitive and will not race or hunt.

The 24,000 k.W. German Units.

Penstock and Trash Rack

The penstock for the German units are 23 ft. in diameter, but otherwise oriented similar to that of the English units. The bellmouth is rectangular in section, but the bellmouth curves are different from that of the English units (see fig. 9). In this case also, the penstock changes from rectangular section to circle through elliptical fillets in the transition reach. For the balance length of the penstock, rivetted steel liner is provided.

The Trash rack structure and racks are identical to that for English units (see fig. 6)

Scroll case

The scroll is also of rivetted steel plate construction and is shaped to create the suitable intake vortex, ensure smooth flow with the minimum friction loss and give almost complete immunity from erosion. At the penstock end, the scroll case is welded to the penstock without any reduction in diameter.

Draft Tube

The draft tube is of the Voith elbow type. The steel liner in this case extends from the throat through the entire length of the elbow also (see figs. 8 & 10). Otherwise, the draft tube is similar to the English units with central pier dividing the flow into the sections. Access man-hole is provided for inspection of the draft tube.

Generating Unit

The unit consists of a vertical shaft, single runner Francis type, directly coupled to a vertical shaft, revolving field type generator, generating 3 phase alternating current at 50 cycles and 11,000 volts and having rated capacity of 27,000 k.V.A. at 0.9 lagging power factor. The rated capacity of the turbine is 34,500 B.H.P. at 104 to 120 feet head with a normal speed of 150 r.p.m. Further details of the turbine are as follows:

Plate 7—Down stream view of English-unit draft tubes soon after completion.

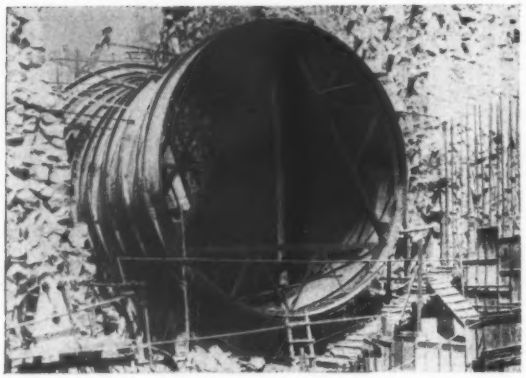


Plate 8—German unit penstock steel liner under erection

Specific speed	79 R.P.M.
Maximum runaway speed—normal	360 R.P.M.
Theoretical	375 R.P.M.
Efficiencies at a head of 95 to 110 ft.	
(a) On full load	88 per cent
(b) On three-fourth load	89 per cent
(c) On Half load	81 per cent

The generator has the conventional bearing arrangement of thrust bearing above the rotor.

The governor with the turbine satisfies the same specification as in the English units.

House Service Unit

This consists of a horizontal shaft, overhung, English Electric reaction turbine, with outside gate regulations, directly coupled to a horizontal shaft generator with a rated capacity of 562 k.V.A. at 0.8 power factor, delivering the output at 400 volts. The rated capacity of the turbine is 630 H.P. at a net head of 87 ft. with a normal speed of 600 r.p.m.

Power House Building

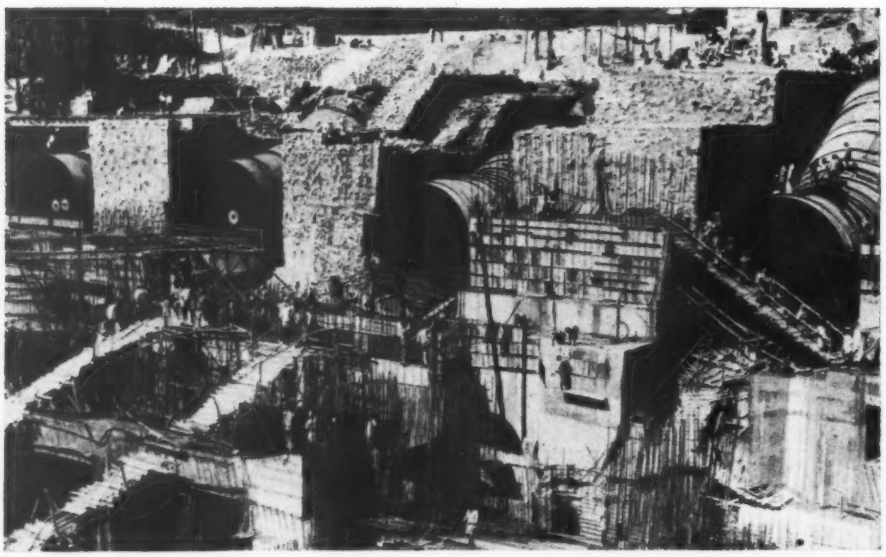
Main Machine Room

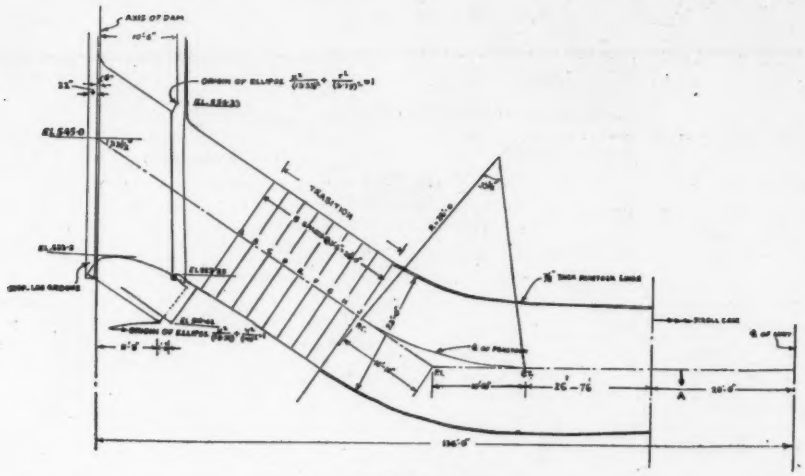
The Power House is a reinforced concrete building 70 ft. wide and 405 ft. long. The Power House consists of two floors, the turbine floor and the Generator floor. Upto the turbine floor, which is at E.L. 510, it is all solid concrete, except for the spaces occupied by scroll cases and draft tubes. Above this floor, 6 ft. thick, reinforced concrete, Power House walls are raised to the Generator floor level at E.L. 527. The generator floor is of reinforced concrete beam and slab construction supported by the Power House walls and suitably placed columns. Above the Generator floor, 6′x3′ R.C.C. columns at approximately 20 ft. centres are raised from either side wall to support the Power House roof at E.L. 593. At the contraction joints, two columns 6′x2′ are provided side by side. These columns are braced by the 3′x6′ crane beam at E.L. 569 and a 4′x2′ bracing at an intermediate height. A steel roof truss is provided to act as additional cross bracing at the top of the columns and also support the 4″ R.C.C. roof slab over steel purlins at 4 ft. centres (see figs: 7 and 10). Reinforced brick pannel wall is provided between the R.C.C. columns and braces. On the upstream side, duble wall is provided so that the space between the walls can be used as air ducts for circulating pre-cooled air in the Power House

In the turbine floor are located the governors, actuators, oil pressure tanks and other auxiliaries.

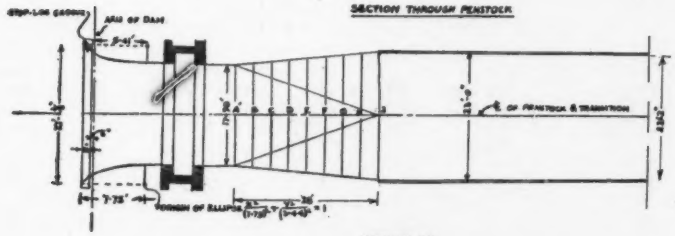
At the generator floor level, 108 ft. length of the floor at one end of the Power House is set apart as a Service Bay which provides ample space and pedestals for erection and maintenance of generators, runners and other equipment. The House Service unit is located on the 510 floor below Service Bay to save space on the generator floor. Access to the Service Bay for bringing equipment is provided by a roadway as well as B.G. Rail track entering insid the Service Bay. The rail track links the Service Bay with the Sambalpur Station, so that heavy equipment can be directly

Plate 9—Construction of the Dam and erection of penstock steel liners in progress.





SECTION THROUGH PENSTOCK



SECTION AA

FIG. 9:- DETAILS OF PENSTOCK FOR GERMAN UNITS

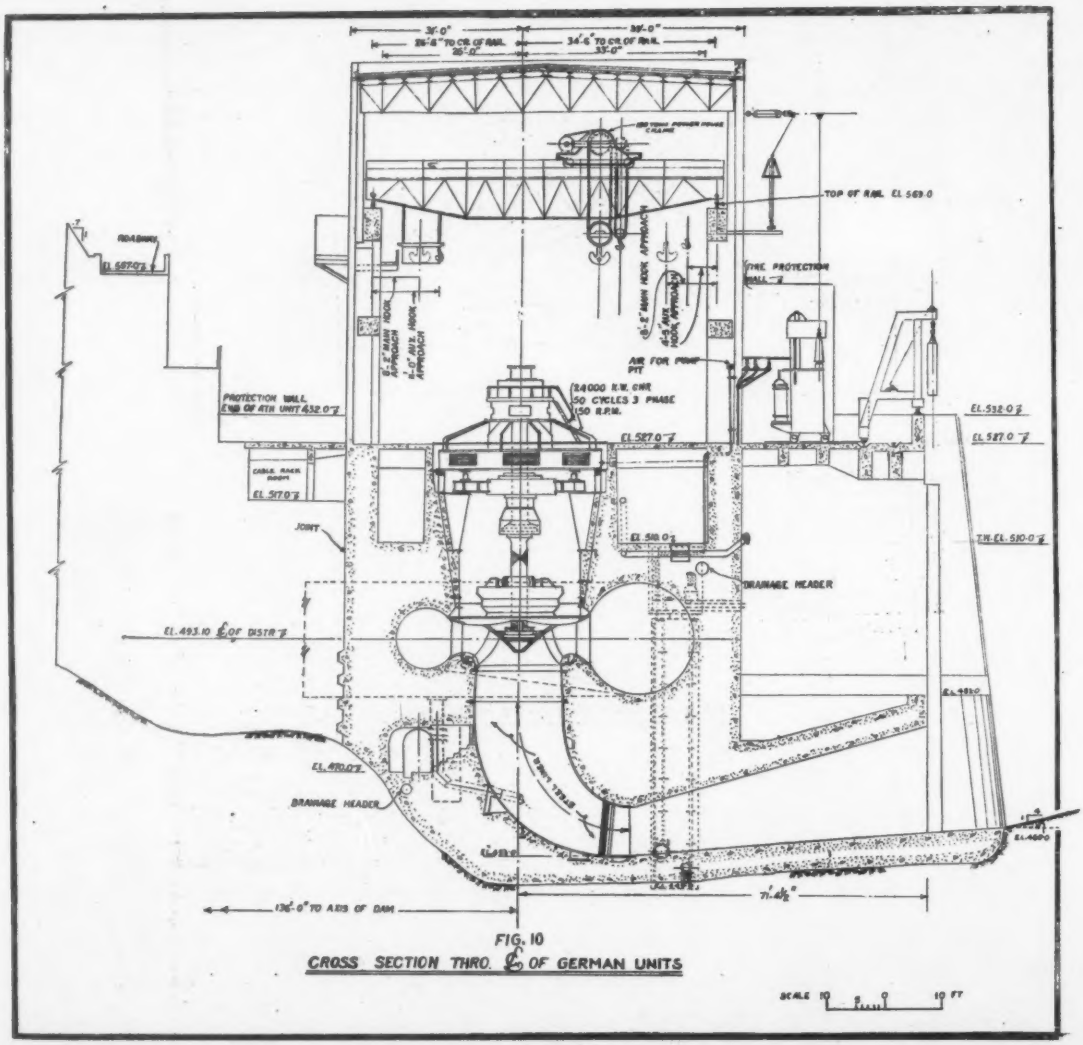


FIG. 10

CROSS SECTION THRO. ℄ OF GERMAN UNITS

Plate 10—German unit scroll cases under erection.

brought to the Service Bay and handled by the Power House overhead crane. Suitable hatches are provided all over the Generator floor for the Power House crane to handle equipment on the turbine floor.

Inspection Gallery

A gallery for the purpose of providing access to the draft tubes is located at R.L. 470 and runs throughout the length of the Power House. The gallery is connected to the Generator floor by means of shafts with hatch covers to facilitate lowering of turbine gratings etc. to the gallery.

Drainage

For station drainage and also for dewatering the scroll cases and draft tubes, for inspection, sumps are provided below the lowest level of the draft tubes. A common sump is provided for the English units and individual sumps for the German units. Dewatering pumps, which will start automatically when the

Plate 11—Francis type runner for the German unit.

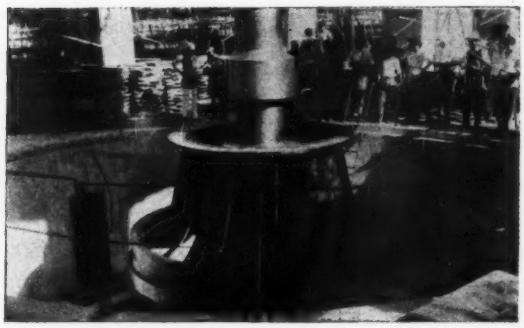
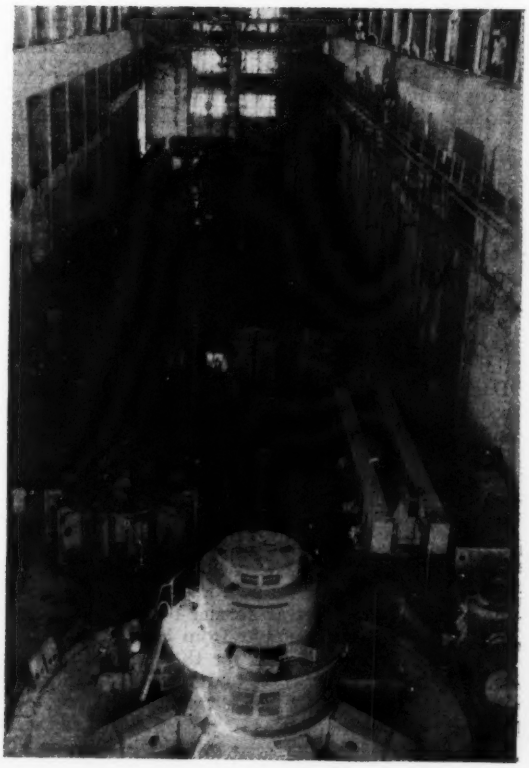


Plate 12—Finished view of German unit and erection work of other units.



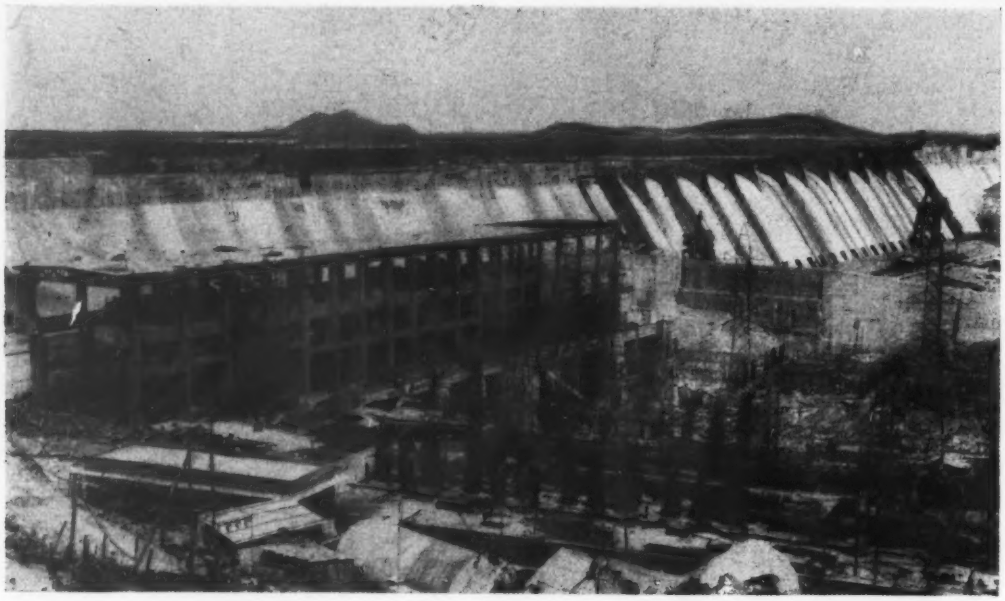


Plate 13.—View showing the columns and bracings construction of Power House superstructure.

water level rises above a predetermined level are provided for these sumps. For complete dewatering of the unit, a screened, valve-controlled outlet leading into the Sump is provided at the lowest point of each draft tube.

Draft tube deck

A reinforced concrete bridge like decking is constructed over the draft tubes at the same elevation as the Generator floor. The main transformers of the Power House are located on this deck at R.L. 527. The transformer tanks are provided with bidirectional wheels and suitable rail tracks are provided on the draft tube deck, linking with the main track entering Service Bay, so that transformers can be moved into the Service Bay for servicing etc. A five feet high R.C. parapet is provided on the Tail Race side of the transformer deck to give additional free board against unexpected rises in the Tail race water-level.

Auxiliary Rooms

Four floors of auxiliary rooms are provided between the main Power House and the downstream face of the Dam. Control room, shift Engineer's room, Reception room, Battery an D.C. rooms, cable rack and spreading rooms, recreation rooms. First Aid room, Kitchen, Toilets and all such, are included in these. A well equipped machine room is provided just adjacent to the Service Bay with direct access to it.

Electrical lay-out

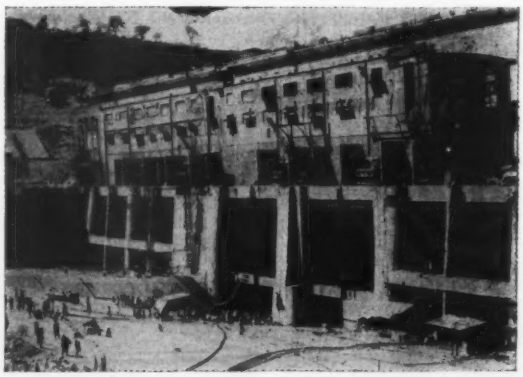
The 11 k.V. leads from each of the Generator are directly connected to its own main step-up transformers located on the transformer deck. These transformers step up the voltage from 11 k.V. to 132 k.V and are rated at 42 m.V.A. for the 37,500 k.W sets, and 27 m.V.A. for the 24,000 k.W. sets. The high voltage leads from the main transformers are taken over the Tail Race to the 132 k.V Switch yard, which has a double bus arrangement. Distribution line at 132 k.V. and 66 k.V. take off from the Switch yard to the different sub-stations. 132 k.V/66 k.V. step-down transformers are located in the Switch yard for feeding the 66 k.V. lines.

Gates, Cranes, Elevators etc.

Penstock Head Gates

At the downstream end of the penstock bellmouth, fixed wheel type head gates are provided for all penstocks. They shall be operated by hydraulic hoists installed in Hoist Chambers at about E.L. 630, inside the body of the Dam. By-pass pipes are provided for letting in water to the downstream of the head gates for equalising the pressure before opening these gates after long closures. A 5′x7′ gallery running the full length of the Power Dam at E.L. 628 interconnects the Hoist Chambers. In the case of the German units, the hoists are electrically connected to the turbine governor so that the penstock head gates close automatically in case of governor failure.

Plate 14.—Downstream view of Power House with main transformers in position on the draft tube deck.



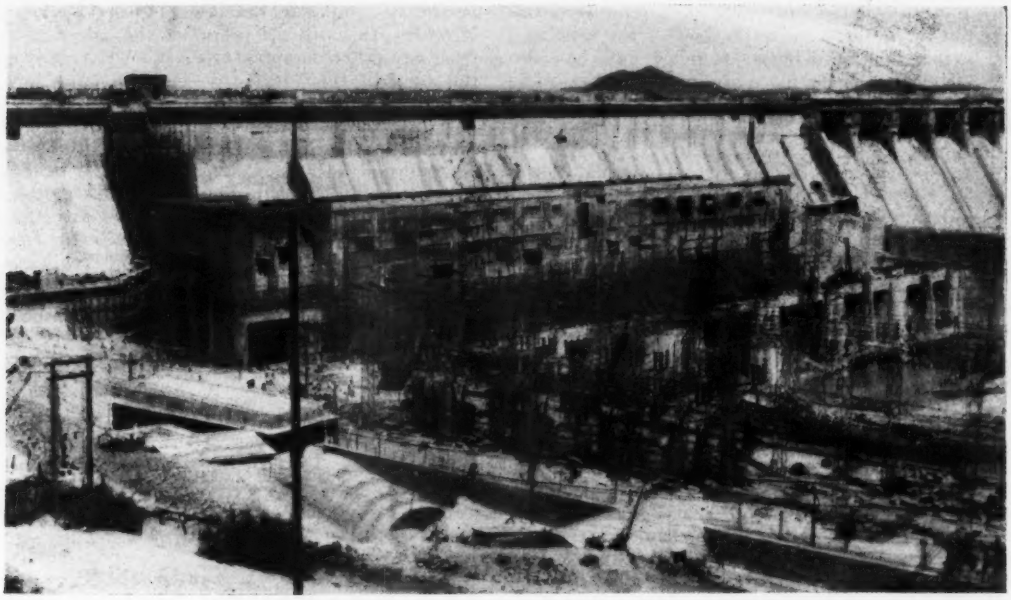


Plate 15.—Power House and switch yard nearing completion.

In the case of the House Service penstock, a butterfly valve is provided instead of a head gate.

Penstock stop logs

At the upstream end of the bellmouth at the face of the Dam, grooves and guides are provided for installing stop logs. Stop logs will be used only on rare occasions, when the penstock head gates are to be removed for maintenance. The stop logs are expected to be installed only when the reservoir level is below R.L. 595, which is the top of the Trash rack structure.

100-*Ton Gantry crane*

An electrically operated 100-ton Gantry crane will be provided on the top of the Dam to serve the Power Dam and the Right Spillway. The crane will move on rails, fixed on the top roadway, at a gauge of 22 feet. The penstock stop log sections will be hoisted by this Gantry crane.

Draft tube bulk heads and hoisting Gantry

Bulk head gates are provided at the downstream end of each draft tube. A 30-ton Gantry crane to be installed on the transformer deck will handle the draft tube bulk heads.

Power House Cranes

Two 150-ton single trolley, motor operated, overhead travelling cranes with lifting beams and 25 ton auxiliary hoist for each, are installed in the Main Power House. These are to handle all the erection works of the turbines and generators and other auxiliary equipment inside the Power House. Through a special lifting beam, which can be attached to the main hooks of the crane, the two cranes can work together to lift extra heavy equipments. The main travel of the crane is on rails fixed on the crane beams at R.L. 569 (See figs. 7 or 10).

Elevators

One 8,000 pounds capacity passenger-cumf-reight lift is being installed between the Dam and the Power House Service Bay. This elevator with a speed of 200 feet per minute will serve as a convenient means of transport between the Power House and top of the Dam, and also the intermediate Power Dam galleries at Eln. 557 and 628. Another smaller lift is being installed in the Auxiliary room area of the Power House to link the Generator floor to the Control room and Reception room and also the main approach road to the Power House at Eln. 557. This forms one branch of the main road from Burla to the Dam and joins an eleven feet wide road formed on the down-stream face of the Dam and running behind the Power House.

Illumination

The auxiliary rooms and the Power House shall be well lit by artificial illumination. Control rooms are illuminated by fluorescent lights to give an illumination of 15 lumens at the operating desk. The Generator room will be lit with powerful pendent lamps to an intensity of 5 to 10 lumens at the machines.

Ventilation and air conditioning

The entire Power House shall be artificially ventilated by a set of blowers located in the Auxiliary room area. Filtered air blown through cooling sprays will be directed through ducts to the various floors and a set of exhaust fans provided on the Power House walls will aid the circulation.

Full fledged air conditioning is being arranged for the Control room, Shift Engineer's room and the Reception room.

Future Units

The first stage has utilised only 4 of the penstocks out of 7 installed in the Dam. The fifth and sixth penstocks have been closed by temporary gates installed in the head gate groove. The seventh pen-

stock has been closed with a 5 ft. thick reinforced concrete plug a few feet inside the face of the Dam and as a further line of defense, stop log gate has also been installed. Generating uints for penstocks 5 and 6 are expected to be installed in the near future. In fact, the installation of the 5th unit, has already been approved by the Government to be taken up in the second stage along with the second Power House at Chiplima. With the commitment on irrigation and flood control, there is not enough water to run the 7th unit unless another reservoir comes up in the upstream reaches of the Mahanadi or its tributaries and therefore, the seventh penstock is not likely to be required for use in the near future.

On this basis, the excavation for the foundation of the fifth and sixth units have been completed and 3 to 5 ft. thickness of concrete placed to cover the rock surface. Since the future units have not yet been ordered, the draft tube shape and bottom level etc., are not known. Hence the foundation excavation has been done to the lowest level, likely to be required by any type of reaction turbine. To facilitate future installation of these units, the downstream Power House wall and the portion of the draft tube from the dwnstream Power House wall to the Tail Race end including the Transformer deck has been constructed for units 5 and 6 (See fig. 11). The draft tube shape and stop log grooves have been done similar to that for English Electric units. However, this will not prejudice the use of machines from any other manufactures as they can easily adjust the shape of their draft tubes to utilise the part construction already done. In the case of the seventh unit, the foundation excavation has only been partly done and instead of constructing part draft tube and Transformer deck, a cellular Coffer Dam in masonry with sand filling inside, has been constructed outside the draft tube line and junctioned with the draft tube pier on Unit 6 end and the Spillway Training Wall at the other end (See fig. 12). With this arrangement, by lowering stop logs for draft tubes of units 5 and 6, the Power House pit is isolated from the Tail Race and turbine installation work can be taken up after dewatering the pit.

The Tail Race for all the seven units and part length of the Power Channel leading water to the proposed second Power House at Chiplima have also been done. Until the balance length of the Power Channel and Second Power House are completed, the Tail race water is temporarily being diverted into the river.

Acknowledgement

Help rendered by Shri Anjeneyulu, Assistant Engineer and my office staff is gratefully acknowledged.

(*Continued from page* 108)

The Hirakud Workshops

Fig. 8.—A view of Machines in the Machine shop occupying total floor area of 11500 SFT. with 51 nos of Machines

tolerances and other specifications in the process of assembly of engine parts. Inspection, at different stages of assembly work, is carried out by an Assistant Foreman, in accordance with these specifications. Observations made and readings taken by him are recorded under his initials in Inspection Sheets, which form a permanent record for the history of the engines.

Fuel injection equipment testing arrangements for Cummins fuel pumps and injectors and Caterpillar fuel pumps and injectors are available. Most of the fuel pumps are repaired and calibrated in this section, after obtaining spares from the supplying firms. Periodic check up of all these pumps is always done with a view to ensuring efficient performance of diesel engines.

The entire fleet of earth moving machines has a fairly large number of electric storage batteries fitted thereon, which need recharging and occasional renewal of cells. A Battery Charging Section with 5 nos. Charging Sets is established. This can undertake 132 nos. 6 Volt or 66 nos. 12 Volt batteries for charging at one time. A water distillation plant is also functioning in this section, which prepares distilled water enough to meet with the requirements of the Project for maintenance of batteries.

The very large volume of work in the shops and attendant expenditure of material requires a coordinating organisation for supplying and accounting for the material. This is accomplished through a divisional stores, in the shops, which receives the demands of material and spares from all the sections and arranges for their prompt supply.

A Labour Welfare Centre has been provided for workers, fully equipped with fans, seating arrangements and cool drinking water. A Workers' Canteen, on cooperative basis, has also been established for serving tea and snacks during the working hours.

Games such as foot ball and volley ball are provided for recreation to workers and occasionally film shows are also arranged for them.

Training courses for mechanics, fitters and electricians, were introuced for some time under the Technical Training Scheme of Government of India and a number of students qualified in different trades were given qualifying certificates.

It is a matter for gratification that all this onerous task has been performed entirely by Indian staff in all ranks.

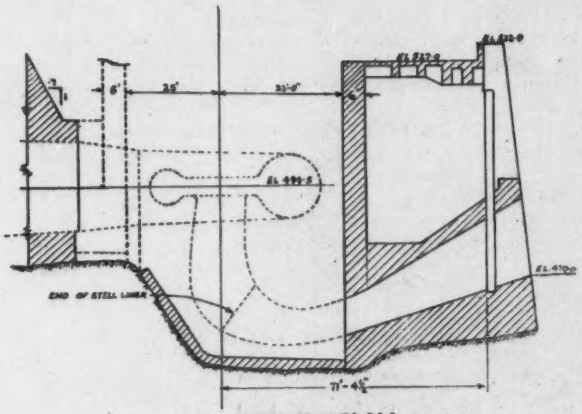
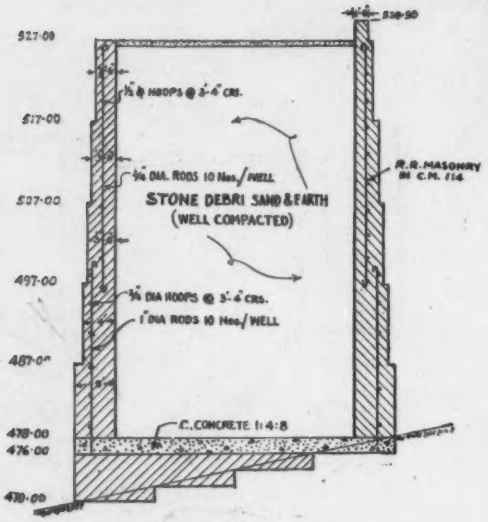
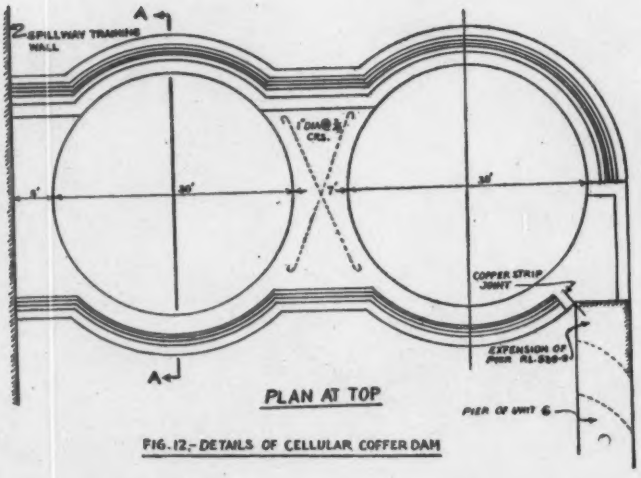


FIG. 11-SECTION OF UNITS 5 & 6.



SECTION- AA.



PLAN AT TOP

FIG. 12:- DETAILS OF CELLULAR COFFER DAM

Stores Organisation

By
N. G. UKE, B.Sc., B,Sc. (Eng.) Hons. (Lond.), A.M.I.E.
Executive Engineer
P. R. N. SARMA, A.M.I.E.
Assistant Executive Engineer
AND
P. D. MITTAL, B.Sc. (Eng.)
Assistant Executive Engineer

N. G. UKE

The Hirakud Project organisation had to meet considerable difficulty in handling its stores. This was not only because it had to deal with large volumes of materials but also because it had purchased a very large stock of construction equipments and stores from the army disposals. The Stores Organisation of the Project has now grown into a systematic and efficient unit and deals with assessment of requirements of different consumers, purchase, storage, distribution and transportation and delivery of the materials at site, and accounting and payment to the suppliers of stores. These various aspects are dealt in the following contribution.

The three essential requirements of any modern construction work are men, machines and materials. Although these three factors have got their own individual importance, it is expected that in this age of automation, there would be a large-scale reduction in the requirement of men ; but the place of machine and materials would assume greater importance. On any construction work by far the largest amount is always spent on the machines and materials i.e., in other words, the stores. On the Hirakud Dam Project the expenditure on stores constitutes about 70% of the entire cost of construction. It needs no emphasis that the progress of work and the achievement of the target in scheduled time depends on the efficient and timely supply of the materials required for the construction. The Stores Organization, therefore, has a very important place in the construction works. This organisation has to place and ensure the phasing of the supplies to synchronise with the programme of works. Any failure or delay in the supply schedules affects the execution programmes and results in serious delays and consequent postponement of the target dates. Hence lot of skill and experience is required for the proper functioning of the Stores Organization on which the entire programme of work depends.

The Stores Organization covers the field of assessment of the requirement of different consumers, purchase, storage, distribution and transportation and delivery of the materials at site of works and accounting and payment to the suppliers from whom the stores have been procured. The purpose of starting the Central Stores Organization was to reduce the work of the construction divisons in respect of the procurement of the stores right upto the site of construction, thus leaving these divisions to concentrate entirely on the actual execution. The construction engineers did not even have to spend any time in the accounting of the stores since the materials were issued chargeable to the works concerned and all that was required of the construction divisions was to maintain only "Material-at-Site Account".

It has been a very gigantic task to set up a well organised Central Stores since the volume of work involved was huge and the staff available for doing this job was not adequate and sufficiently experienced. The early history of the Central Stores Organization is interesting. Soon after the Project was sanctioned, the importance of immediate procurement of stores was realised and no time was lost in buying the machines and materials from the army and other disposals. This procurement proved very useful during the construction of this Project. It was unfortunate that the importance of adequate staff was not appreciated in time and serious confusion resulted in the accounts of the stores. The influx of the stores was very heavy and the staff was too inadequate to cope up with the work involved in receiving and checking the consignments and bringing them to account in time. We had to fight against serious odds and bring the Central Stores to the shape as it exists now.

Since Hirakud was not connected with rail link, all the incoming consignments had to be unloaded at Sambalpur in two or three open yards. These were being transported to Hirakud by trucks which could not cope up with the inflow of the consignments at Sambalpur, as a result of which there was a lot of accumulation of consignments at Sambalpur. The consignments being brought by trucks to Hirakud daily, though inadequate to clear the Sambalpur yards, were too large for the staff posted at Hirakud to cope up with its receipt, verification and accounting. The materials, therefore, had to be only dumped in the Central stores yard in several heaps. The photographs in the next page show how the stores were seen at that time.

In those days the Central Stores area was uneven because of the small hillocks and mounts and there were no proper sheds, roads and drains. All these factors contributed to the confusion and created unwarranted arrears in the stores accounts.

Gradually Hirakud was connected with the rail link and sanction of the staff was also increased. Due importance was given to Central Stores Organization and it was recognised and established as a separate entity under an Executive Engineer. This was in August, 1949. Till this time stores were attached as a part to one division or the other. This newly formed division had to do a lot of spade work and to shoulder the legacy of an unorganised past which it succeeded in doing and bringing the Stores Organization upto-date on the modern commercial lines. The immediate problem was to check up and verify all the consignments that were strewn all over the yard and bring

Photograph showing stores heaped in the Central Stores Yard.

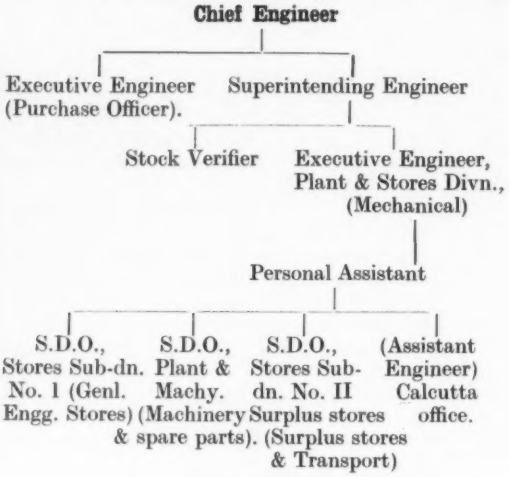
them on books as they existed on ground. Great difficulty was experienced in identifying the stores which were not properly tagged or for which no packing lists were available. With whatever knowledge the store keepers and the supervisors had at that time, they tried to identify and give the nomenclature to the materials in their own way. The orthodox P.W.D. system of stores accounting and maintenance of registers did not prove equal to the task and a new Bin-Card system based on the commercial accounting was introduced. One Bin Card for each item was opened giving details of the description and part number. These were bound in the loose leaf binders. The Bin Cards also contained details of the receipts, issues and the balances after every transaction, issue rates, quantity on order, annual consumption, maximum recoupment and danger levels. It also gave the exact location of the materials in the godowns. Each Bin Card was given the code and serial number.

In the second quarter of 1951 almost all the stores were thus taken on the Bin Cards. This was a great start and was probably the first time when the store keepers knew exactly what was under their charge and where exactly it was located. The stores were gradually organised, good roads and sheds were built and covered and secured accommodation was provided for almost all the stores.

The photograph on page 101 shows the stream line appearance of the stores as it exists to-day.

Quite a lot still remained in the outside-yard since it was impossible and uneconomical to provide covered accommodation for all sorts of material. A very strong security organization was also instituted and no material could go out of the boundary walls of the Central Stores without a proper material gate pass in the printed form duly signed by a Gazetted Officer.

In August, 1953 the Purchase Section was separated from the Stores Division and was constituted directly under the Chief Engineer. This left the Stores Division with sufficient time to concentrate on the receipts, issues, distribution, transportation, payment and accounting of the stores. The present set up of the Project Stores Organizaton has the following units and functions :—


Chief Engineer
Executive Engineer (Purchase Officer).
Superintending Engineer
Stock Verifier
Executive Engineer, Plant & Stores Divn., (Mechanical)
Personal Assistant
S.D.O., Stores Sub-dn. No. 1 (Genl. Engg. Stores)
S.D.O., Plant & Machy. (Machinery & spare parts).
S.D.O., Stores Sub-dn. No. II Surplus stores (Surplus stores & Transport)
(Assistant Engineer) Calcutta office.

Purchase Section

This section is under the direct control of the Chief Engineer and is in the charge of a Purchase Officer. The duty of this section is to receive requisitions for stores required by the Divisions, scrutinise them and take procurement action by placing purchase orders taking into consideration the existing stock position, quantity on order and the annual consumption of such stores. The procurement action is taken by inviting tenders from the market and then placing the purchase orders, or by operating on the running rate contracts concluded by the D.G.S. & D., or at times by placing indents on D.G.S. & D. The copies of the purchase orders are endorsed to the Executive Engineer and Sub-divisional Officers of the Stores Division who are responsible for the receipts of the stores and arranging payment to the suppliers. A copy of each of the purchase order is also endorsed to the requisitioning officer, the Financial Adviser & Chief Accounts Officer and the Deputy Accountant General (Resident Audit Officer).

Being a Government organization, the Project purchases are normally supposed to have been made through the Central Purchase Organization of the Government i.e. D.G.S. & D., New Delhi. But it has been experienced that this system did not suit the requirements of such projects as that of ours which have a tempo of war-like expediency, where even the slightest delay would do damage irreparable to the construction schedule. It has been found absolutely necessary to by-pass this channel and resort to direct purchase in order to maintain the schedule of completion of works. The Government was also convinced of the importance of giving enhanced purchase powers to the Project authorities and as a result the following powers were sanctioned :—

Chief Engineer : Rs. 40,000/- per item for every single purchase without any restriction on the method of purchase.

For purchases beyond Rs. 40,000/- without going through D.G.S. & D., by getting the prior approval of the Control Board under *emergency procedure.*

Purchase Officer : Upto Rs. 1,000/- per item for every single purchase without any restriction on the mode of purchase. Upto Rs. 5,000/- in the case of lowest tenders being accepted. If lowest tender is not accepted

and value exceeds Rs. 1,000/- Chief Engineer's approval is required.

During the last three years of the working of this Section it has processed on an annual average of 1000 requisitions for supply of materials and the total purchases made has been approximately Rs. 797 lakhs as detailed below:

	From 1953 *to July*, 1956. *Amount in lakhs*	*Average per year* lakhs
Spares ..	237	66
Iron and steel ..	113	31
P. O. L. ..	71	20
Cement ..	292	82
General stores etc.	84	24

Stores Division

This Division is responsible for the receipts, issues, storage, accounting, transportation to site and payment of the bills of the suppliers. It is also responsible for the maintenance of the depreciation accounts of different machines working all over the Project on different works.

The staff sanctioned for the works connected with the stores is as under :—

Executive Engineer ..	1	Upper Division Clerks	23
Assistant Engineers ..	4	Lower Division Clerks	44
Supervisors ..	16	Senior Draftsman ..	1
Store Keeprs ..	15	Tracer ..	1
Assistant Store Keeprs ..	24	Superintendent, Liaison and Transport ..	1
Accountants	2		
Head Clerk ..	1	Traffic Inspector ..	1

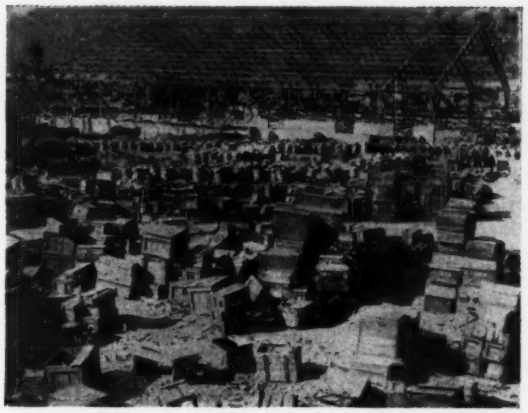
Though this staff is equal to about 3 times that of a normal Division, it is hardly sufficient to cope up with the voluminous work that this Division has to do. Besides this regular staff a large contingent of workcharged staff whose monthly pay-roll amounts to Rs. 30,000/- is also employed in the stores.

The work is divided into the following sub-heads:

(*i*) Receipts and Claims.
(*ii*) Storage, Accounting and Issues.
(*iii*) Materials Transport.
(*iv*) Surplus Stores.

Receipts and Claims

There are two types of consignments viz., smalls and full wagon loads. The consignments which are booked as smalls have to be taken delivery of at Sambalpur Railway Station for which purpose there is a Section established at Sambalpur near the rail head. It is the duty of this Section to take deliveries and arrange for the transport of these consignments to Hirakud Central Stores by our own Hirakud Dam Railway wagons. The full wagons consigned to the Executive Engineer, Plant & Stores Division (Mechanical) are placed by the railway loco in the Hirakud Exchange Yard which is the Hirakud Dam Project siding and they are hauled to the Hirakud Central Stores or other Project sidings such as Burla, Gousala and Chiplima by our own Hirakud Dam Project locomotives. In order to facilitate lodging of the claims on the railways for the short delivery of consignments in these full wagons, one Assistant Goods Clerk has been posted for this purpose on the request of the Hirakud Dam Project by the railway



Another photograph showing stores lying strewn all over the open Stores Yard

authorities. It is his duty to witness the shortages at different sites of unloading and give a shortage certificate to that effect. The debit for the pay and other allowances for the railway staff, i.e. Assistant Goods Clerk and his peon is the liability of this Project.

Another Section under the charge of this Division is established at Calcutta from where maximum of our supplies come. The duty of this Section is to chase up the supplies, arrange for railway wagons, whenever necessary and pursue the claims on the railways. This is under the charge of one Superintendent, Laison and Transport. To eliminate delay in their receipt of consignments and avoid the hold-ups at different railway junctions, one Wagon Chaser has been posted with headquarters at Chakradharpur.

On receipt in Central Stores, the consignments are opened and checked by technically qualified supervisers who record them on the goods-received-sheets which have replaced the old measurement books. The goods-received-sheets are prepared in triplicate, original and duplicate being detachable. Hence at the time of payment unlike the measurement book the whole g. r. book does not have to move with the suppliers' bills. This ensures very prompt payment and facilitates the work to a great extent. Usually, payment of the suppliers' bills is made in about a month's time. Special arrangements have been made for immediate payments in the cases of cement, steel, spare parts of machineries etc., where 90 per cent payment is made in advance and in some cases even hundred per cent.

After the material, as entered in the g. r. sheets, is finally accepted by the Sub-Divisional Officer incharge, it is handed over to the Store Keepers for bringing on their Bin Cards, storage and subsequent issues.

Storage, Accounting and Issues

Stores are divided into the following classifications :

General Stores :	*Plant & Machinery Stores* :
1. Building & Miscellaneous materials.	1. Machinery
2. Metals.	2. Diesel Engine Spares.
3. Pipe & Sanitary Fittings.	3. Petrol Engine spares.
4. Electrical Materials.	4. Auto spares.
	5. Crane & Shovel spares.
	6. Earth-moving machi-

5. Small Tools (Ordinary T & P)
6. Iron Mongery.
7. Railway and Bridging materials.
8. P.O.L., Tyres, Tubes etc
9. Cement.
7. Pneumatic Tools and nery spares spares.

The total value of the stores now held by this organization is 7.44 crores inclusive of spare parts. Besides this, the total cost of the machines purchased is 7 crores (approximately). The total number of items held is over 91,000. The average monthly turn-over is :

Receipts	..	Rs. 26,64,000/-
Issues	..	Rs. 26,33,000/-

Monthly stock accounts of receipts and issues are submitted to the Financial Adviser & Chief Accounts Officer, Hirakud Dam Project on the modified combined forms (1) P.W.A. 8 and 9 combined and (2) P.W.A. 8 and 10 combined. These are prepared (issuing) section-wise, (consumer) division-wise, and estimate-wise for the whole Project to facilitate easy adjustment of expenditure by Financial Adviser & Chief Accounts Officer.

The construction engineer is relieved of the work of maintenance of stock accounts for submission to Financial Adviser & Chief Accounts Officer and compiling their subsequent bookings against various works. The ready booked figures are easily available for incorporating in works Registers. As many as 51,000 foolscap size sheets are consumed by the Store Keepers every year for compiling the Stock Accounts for about 20 Divisions of the Project operating an average of 400 sanctioned estimates annually.

Plant & Machinery and Spares

All the plant and machinery of the Project have been classified into 10 groups namely, (1) Exploratory Machinery, (2) Earth Moving Machinery, (3) Concrete Plant & Machinery, (4) Transport Vehicles, (5) Rolling vehicles (6) Workshop equipment, (7) Miscellaneous Machinery (8) Electrical Equipment, (9) Tankers, (10) Pumps; and ownership cost estimates have been prepared for each group separately, inclusive of the cost of machines, repairs, overhauling and spares required throughout its life time. These estimates are operated by the Stores Organization. All spare parts are accounted for as "Q Special Tools & Plant Spares" in form No. C.P.W.A-13 on their receipt and form 14 on their issue to construction divsions for consumption on different machines. This system has brought great relief to the mechanical engineers of this Project who were thus rid of the problem of framing and operating the spare parts estimates. This ensured continued operation of a machine even on its transfer to a new division since this division did not have to wait for any estimate for spares etc. These had been already sanctioned for him and were being operated by the Stores Division. What is required from these operation engineers is only an efficient up-keep of operation records and their timely submission to the Stores Organization. The stores in turn would raise suitable debits on the basis of depreciation rates for the equipment.

This system has also the advantage of easy location of idle plants and their subsequent disposal.

The estimates of ordinary tools and plants are also being operated by the Stores. The Stores Organization will be acting as a Central Tool Room for the entire Project. The construction engineer will have only to collect the tools required by him as and when necessary, and keep their subsequent numerical accounts.

Pricing of Stores

A Pricing Section for pricing each of the 91,000 items held by Stores Division is in operation directly under the control of the executive engineer of the Stores Division. The prices so fixed, called the Issue Rates, are published in the form of Price Circulars and are also entered on the individual Bin Cards of the store keepers. The basis adopted is to cover all the trade incidental charges e.g., insurance, freight, duty, D.G.S. & D. inspection charges etc., above the basic rate at which the stores are purchased. On the issue rate 3% storage which is subject to revision, is charged by the Stores Divison to the works to cover up the expenditure on care, custody, handling and transport of materials and the cost of workcharged staff employed for this purpose. This percentage has been brought down from 10% in 1950 to only 3% in 1956.

Payment of Bills

The bills for supply of materials are originally received by the Executive Engineer in-charge of Stores. These bills are initally got verified with the supplies made from the Stores Sub-Divisional Officers who are primarily responsible for the receipt, inspection and accounting of Stores. At the second stage the bills are scrutinised and passed for payment by the Accounts unit of the Divisional Office. At the final stage, these bills are audited by the Financial Adviser & Chief Accounts Officer and the cheques thereof issued for payment to the firms. This Accounts unit has handled as many as 600 bills per month.

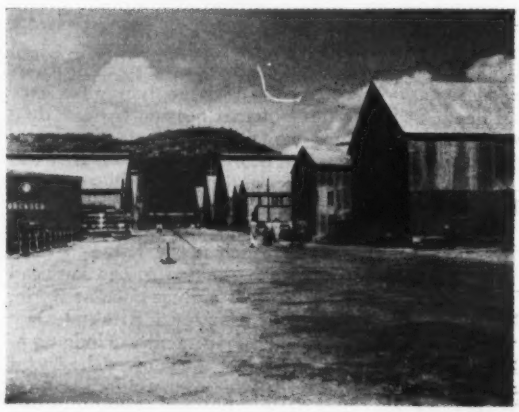
Debit Accounts of Issues

The monthly issue accounts submitted by the Stores Sub-divisions are scrutinised by the Stores Division Accounting Unit and the debits against the various executive divisions are made out by this unit and forwarded to Financial Adviser & Chief Accounts Officer for final adjustment. The priced Stock Ledger is also maintained by the divisional Accounting Unit.

Material Transport

A separate material transport system has been set

Stores as now stocked at Hirakud Central Stores Yard.



up. Routine truck services are run by this section from the Central Stores to the various work sites. The consumers after drawing their requirements from Central Stores handover the materials to this transporting agency for delivery at the site. In emergent cases, however, the consumers are at liberty to carry the material to the site themselves. This material transport service caters to the demand of construction engineers throughout the Project area, as well as to distant places like Cuttack, which is over 150 miles.

Special Arrangement

The following special arrangments have been made for the distribution of vital supplies:—

(*i*) *High Speed Diesel Fuel Oils* :

A spectacular feature of this Project is the huge quantity of earth work involved, as much as or probably larger than that required for the construction of a highway from Kashmir to Cape Comorin, besides the quantities of concrete and masonry. For achieving this programme expeditiously and efficiently, the huge fleet (worth about Rs. 7 crores) of earth moving machinery, concrete machinery and other construction equipments has been working round the clock for the last 6 years. To keep the breakdowns to the minimum, the supply of clean and well filtered fuel was to be ensured, since most of the breakdowns of diesel engines are attributed to unclean and bad fuel oil. To solve this problem a system of refuelling the machines through the diesel pumps and filters was organised and over half a dozen fuel oil pumps were installed at suitable work sites. By the time oil is delivered in the machines it would have already passed through at least three filters at various stages. These pumps were working round the clock for keeping the gigantic wheels moving. Regular supplies of fuel oil to these pumps are being maintained from a large depot by special arrangement with an oil concern, under the vigilant control of the Stores Organisation. About 15 thousand gallons of fuel oil were being put in the gigantic machines every day. The stores organization supplied about 60,00,000 gallons of clean fuel oil to the Project machinery during the last three working seasons.

Petrol supply to the Project vehicles and for other machinery is arranged through the agency of an oil company similar to the fuel oils.

Suitable arrangements have been made for the distribution of cement, steel and other heavy materials, explosives etc. The train loads of these materials are carried direct to the work sites where sub-depots have been organised.

Security

A strong security organization is absolutely essential to guard the stores of such huge value. This has been achieved by the employment of ex-military personnel. The total strength of the Security Staff is (*i*) Jamadars 3 and (*ii*) Chowkidars 63 in addition to some supervisory staff under control of the Sub-divisional Offcers on behalf of the Executive Engineer. This Organizations is now working with complete co-operation of the Special Security Police force since 1954.

Stock Verification

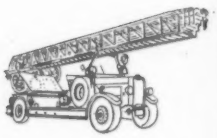
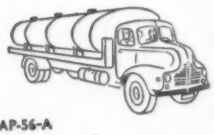
As alredy stated earlier, the stores were taken on Bin Cards by the Store Keeper in 1951 according to his own knowledge of these stores. As was expected the exact description could not be given then. As such the stock verification had to be done by technically qualified assistant engineers and supervisors. The volume of work involved was also too huge for the normal staff of the division and hence sepcial staff was sanctioned for stock verification. This staff was under the control of the Superintending Engineer. The maximum number of officers working at a time on this work was 3 assistant engineers and 18 supervisors. The first round of stock verification was complete only in December, 1955. Now stock verification is a continuous process.

Surplus Stores

As the Project has come to its last phase, an officer has been working to assess the requirements and surpluses of the plant and stores already acquired for the Project. As a result, quite a lot of surplus stores are being disposed off through the agency of the Director General of Supplies & Disposals, either by public auction or by calling for closed tenders or by release to priority indentors. This work has progressed very well by the help of the Director General of Supplies & Disposals. The disposals of the surplus spare parts have been taken up by the Central Water & Power Commission who are responsible for co-ordinating the requirements of spare parts of different projects all over the country. The disposal of machines which have been surplus has been taken up and is progressing well.

Stores Organization is thus a collossal undertaking. It is very essential for any construction engineer to have the stores experience and for the stores officers to have field and construction experience, without which one cannot appreciate the difficulties of the other and full co-operation does not forthcome voluntarily.

In conclusion we have to stress that due importance must be given to the proper planning and manning with skilled personnel of any stores organisation that is proposed to be set up, well in advance of the expected influx of different consignments. This is essential in order to eliminate all consequent confusion and to ensure smooth working of any construction work where materials and machines assume large importance.

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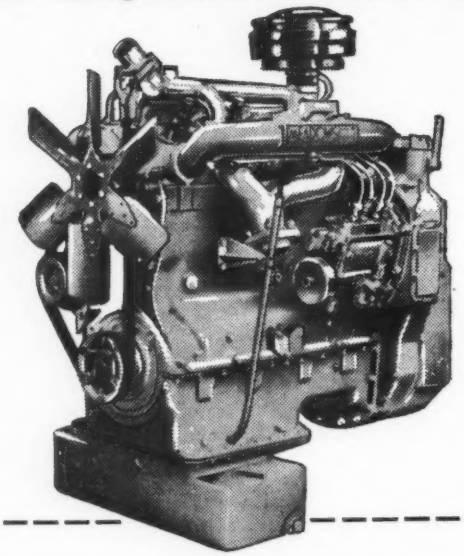

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The Hirakud Workshops

By

S. P. CHUGH, B.E. (Mech.)

Executive Engineer, Mechanical Division

AUTHOR

The problem of maintenance and repair of costly imported machines used in river valley projects has been the headache of engineers and administrators throughout the country. In addition to this problem, a workshop in such a large project site as Hirakud has to undertake a large number of complicated jobs. The following article gives a full view of the growth of the workshop from a small beginning into a versatile unit capable of undertaking intricate jobs. While the economics of its operation has not been touched here, the technical aspects of the workshop at Hirakud need to be carefully noted for future guidance.

The Hirakud Workshops were first established in 1948 with the undertaking of the project work at Hirakud. Simultaneously with the setting up of the shops, a small diesel power house was also erected which was later replaced by a 2,000 kilowatt diesel station with 6 diesel sets installed therein. Installation of the shops continued over a period of four yars, when additions and alterations were made—both in equipment and accommodation commensurate with the demand on the shops for manufacture jobs and overhaul of construction equipment.

The shops, as initially laid out, were not planned for any major production work. However, the demands made on the shops, in consequence of prevalent conditions in the market, characterised by acute shortage of material required for construction work and inordinately long delivery periods, made it necessary to undertake all types of work. All available sources were tapped to render the workshops capable of undertaking all intricate manufacture jobs. This was made possible by the procurement of machine shop equipment and shedding material—partly from the regular market, partly by receipts from German Reparation Machinery and the balance through Disposals Agency. Some equipment was manufactured in the shops itself. In view of the diversity in the nature of work the shops had to be divided into fourteen sections to fulfil different assignments. The names of these sections are as follows:

1. Planning & Production Office.
2. Machine Shop.
3. General Repair & Fitting Shop.
4. Structural and Welding Shop.
5. Carpentry and Foundry Shop.
6. Wagon and Bottom Dump Repair and Overhaul Section.
7. LeTourneau Machinery repair and ovehaul section.
8. Crawler mounted machinery repair and overhaul section including tractors, cranes, shovels, etc.
9. Earth Moving Machinery Servicing Section.
10. Diesel Engine Repair and Overhaul Section.
11. Battery Charging and repairing Section.
12. Miscellaneous Machinery Repair and overhaul section.
13. Divisional Stores.
14. Time, Security and Labour Welfare.

The shops are located at present in a plot measuring 750ft. by 750 ft. On this plot, covered accommodation with a total of 2,25,000 sq. ft. of floor area has been provided for plant and equipment, including passages and alley-ways.

The project strength at its peak period was 20 divisions. With the demands emanating from different divisions, besides those from research laboratory and hospital, and other sources for different types of work, the necessity for a Planning & Production Office assumed paramount importance. The number of work orders received during the peak working period amounted to an average of 25 a day, and reached a maximum of 40 work orders per day. The Planning and Production Office has served as the main accounts organisation for the workshops, besides being responsible for processing of job orders, preparation of job estimates, planning of work, assessment of requirements for men and material for different jobs and finally booking of cost of labour and materials together with raising of debits to different divisions. The master records maintained in the office give a detailed history of the jobs executed with full data regarding the cost estimates, work order nos. etc. as are warranted by the special accounting Memoradum for Workshops for Hirakud Dam Project.

The main equipment in the Workshops is as follows:

Machine Shop.

1.	Lathes—ranging from 4′ bed to 19′ bed with a maximum of 2′-2″ swing.	27	nos.
2.	Radial Drills 2″ dia ..	4	,,
3.	Milling Machines, Universal ..	1	,,
4.	Milling Machines, Horizontal ..	2	,,
5.	Milling Machines, Vertical ..	1	,,
6.	Shapers, Vertical ..	1	,,
7.	Shapers, Horizontal ..	3	,,
8.	Horizontal boring machine, bed 8′-10″	1	,,
9.	Crankshaft grinding machine 54″ ..	1	,,
10.	Surface Grinder ..	1	,,
11.	Bevel Gear Shaper, 500 mm ..	1	,,
12.	Gear Generating Machine 36″ ..	1	,,
13.	Pedestal Grinders ..	4	,,
14.	Power Saw 6″ dia. ..	1	,,

Carpentary.

15.	Band Saw Machine ..	1	,,

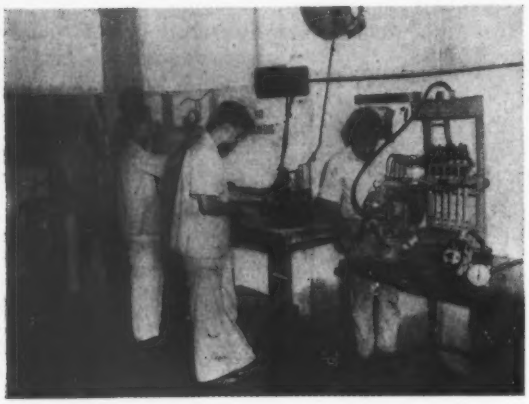


Fig. 1.—Fuel injection equipment repair-section.

16. Planer	.. 1	,,
17. Circular Saw	.. 1	,,
Smithy.		
18. Power Hammer—5 cwts.	.. 1	,,
Welding.		
19. Transfomer chokes capacity 110V/375 amps.	.. 10	,,
20. Rotary D.C. sets with A.C. motor —2 leads—each 11 V/375 Amp...	2	,,

The total installed horsepower with these machines amounts to 500 approximately with a peak load of over 350 horse power under normal operating conditions.

The total strength of labour, incluing workcharged supervisory staff, is over 800 men.

The figure of turnover in the year 1955-56, inclusive of expenditure on direct labour, material and spares, amounts to Rs. 50 lakhs approximately.

The Machine shop with equipment mentioned above constitutes a versatile unit capable of undertaking intricate jobs. Most of the parts required for repair and overhaul of construction equipment can be handled on one or the other machine. Some Turret lathes and Capstan lathes have helped in mass production jobs such as manufacture of bolts, rivets, screws etc. whenever required.

A difficult problem was once faced in grinding the vertical, top and bottom seats for stop logs for penstock gates—the overall dimensions of the opening being 42′×25′. The vertical seats were made out of flats 22′×12$\frac{3}{4}$″ A German lathe with 19′ bed was adapted to take the grinding wheel and motor on the saddle, the traverse being given by the lead screw. The job was mounted by rigging up a structure with a channel platform, and the grinding work completed without difficulty.

Another major job involving work in the Foundry and Machine shops, executed recently, was the manufacture of screw rods and gear boxes for canal shutters. Screw rods ranging from 1$\frac{1}{2}$″ dia to 4″ dia. with lengths upto 17 ft. numbering nearly 200, have been made complete with nuts and capstan handles for their operation.

In connection with concreting work on the Dam, the workshops have made an important contribution in supplying all the requirements of shuttering. The shuttering and forms for concreting the main dam—including sluices and Power House portion (for draft tubes etc.) amounting to over 1,00,000 sq. ft. was manufactured by these workshops. Although handicapped by want of special equipment, which could have augmented the progress on such jobs, improvised means and contrivances were adapted for fulfilling our demands. Bending of angles and plates in different planes, specially to make forms for bell mouth and roof portion of the sluices was done by use of jim crows and fixtures. Some other items of fabrication of consequence done in the shops are listed under :

1. Concrete buckets 2 c.yd.	..	16 nos.
2. Concrete buckets 3 cu.yd.	..	6 ,,
3. Sheep foot rollers, double drum 6 ton capacity	..	20 pairs
4. Sheep foot rollers, 3 drum for rolling against abutments.	..	1 ,,
5. Trash Racks for Power House	..	300 nos.
6. Bulk Head Gates (stop logs) for pen stock—42′×25′	..	2 sets
7. Embedded parts for stop logs for pen stocks.	..	7 ,,
8. Draft Tube Gate for 5 units each, size 25′×9′ (approximately.)	..	5 sets or 20 leaves.
9. Embedded parts for Draft Tube stop log for 7 units	..	7 sets.
10. Towers, type 'A'	..	150 ,,
11. Towers type 'B'	..	15 ,,
12. Power House trusses, each weighing 7$\frac{1}{2}$ tons.	..	23 ,,

The cost of these items are as follows :

1. Concrete Buckets, 2 cu.yd.	..1,700/- each
2. Sheep foot rollers, one pair of two drums (Bearing pressure 300 lbs. per sq. inch.)	.. 4,800/- ,,
3. Shuttering, ranging from Rs. 3/8/- per sq.ft. for straight shuttering and upto Rs. 9/- per sq. ft. for curved plates etc.	
4. Transmission Line Towers for 132 kV & 66 kV (Inclusive of material)	800/- per ton

Fig. .—Diesel engine repair and overhaul section of workshops.

5. Bulk Head Gates and embedded parts (gate leaves weighing over 12 tons each)—inclusive of material. .. 1,600/- per ton
6. Draft Tube Gates and embedded parts (inclusive of material) .. 1,200/- ,,
7. Trash Racks each weighing 2½ tons and roof trusses each weighing 7½ tons (inclusive of material) .. 800/- ,,

In accordance with modern practice in structural engineering, rivets, nuts and bolts have been totally dispensed with in all the items of work mentioned above and welded joints have been adapted to advantage in all cases.

The manufacture of Trash Racks which involves over one lac rft. of flats welded to 300 channel frames reinforced with 90 lb. rail members, posed a great problem in consequence of non-availability of steel flats of proper size from the market. This difficulty was overcome by cutting smaller flats with sizes ranging from 1½" width to 3" width (in different thickness of material ranging from 5/16" to 1/2") from bigger flats ranging from 4" width to 12" width. This was made possible by the use of oxy-acetylene cutting machines.

The workshops, which have been used for production jobs requiring technical skill, though initially handicapped by the dearth of skilled staff, have succeeded in training up their own personnel who are now well versed in different techniques of welding work.

The provision of equipment for testing the welded joints (X-Ray plant) and a stress relieving furnace suitable for big sized jobs will make this workshop a great asset in gates manufacture for projects in the country.

The demand for spares for construction machinery which could not be met with by the supplying firms in the country, has been partly fulfilled by local manufacture through structural shop by process of fabrication as also by casting work in the Foundry. A number of intricate jobs such as gear boxes, thin walled housings etc. for diesel engines, crankcases, and innumerable other parts were made by casting.

Fig. 3—Foundry shop and some items of spares cast there

The Foundry is equipped with a one-ton. cupola. Castings with a maximum weight of 8 cwts. have been made in these shops.

Non-ferrous castings like gunmetal and bronze bushings, aluminium alloy castings etc. have also been very often made here. A well equipped and mechanised Pattern Shop is also attached to the Foundry.

Coming to the repair work handled in the workshops, it may be mentioned that the Project has had to deal with an assortment (by types and makes) of earth moving equipment. Over twentyfour different makes and types of machines numbering over 300 are working on the Project. Quite a number of machines, which were received from Disposals Agency at the outset were commissioned and used until such time as new equipment became available.

The running repair and maintenance of these machines phased over the working period of 8 months and a thorough overhaul and major repairs phased over the monsoon period of 4 months presented a difficult task. However, by planning the lay-out of the shops in different sections with due consideration to the type and category of each item and by distributing the overhauling work over the entire period in a year, the problem has been fairly well solved. The major categories of earth moving equipment are as follows :

(*i*) Bottom Dumpers (Caterpillar DW-20 machines and Euclid),
(*ii*) LeTourneau Machinery (LeT. Scrapers, Tourna Trailers, Tourna Dozers and Tourna Rocker)
(*iii*) Rear Dumpers (Mack Dumpers—model LV, Euclid Rear Dumpers—models 8 TD and B5FD, Sterling Rear Dumpers.)
(*iv*) Crawler mounted machinery (all crawler tractors, Caterpillar, International, Allis Chalmers, Fowler Marshall and Fowler Challenger etc. and cranes.)
(*v*) Basic excavation machines—shovels and loaders.

This division of machinery into broad categories and handling of each category by a separate section has enabled us to specialise the staff in repair and overhaul of specific types in different sections and thus to improve the standard of work.

Fig. 4—Sheepfoot-rollers and concrete bucket, over 20 nos. each manufactured in Hirakud workshops.

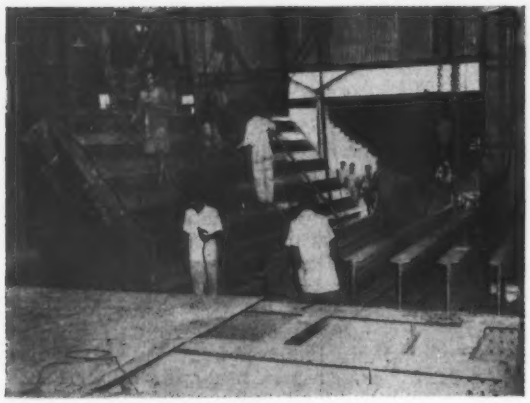


Fig. 5.—Draft-tube gates each weighing over 12 tons made in the work-shops.

Besides earth moving machinery, miscellaneous equipment such as cranes, compressors, water pumps, diesel locos etc. have also been handled for repair and overhaul. This entire fleet of earth moving machinery and other miscellaneous items of machinery brings the number of diesel driven units to over 400. This high figure of diesel powered equipment warrants the establishment of a very efficient and fully equipped diesel engine repair section. This section has been functioning quite well in the Workshops. It is housed in 3 M.B. sheds with floor area of 110′×110′, equipped with engine stands, compressed air lines etc. etc. The fuel injection equipment testing section forms a separate part of this shop. Even in repairs of diesel engines, the work has been simplified by dividing the shops into the following sub-sections:

1. De-greasing and cleaning section equipped with steam jenny.

Fig. 6—Two Koehring cranes lifting Draft Tube Gate Leaf

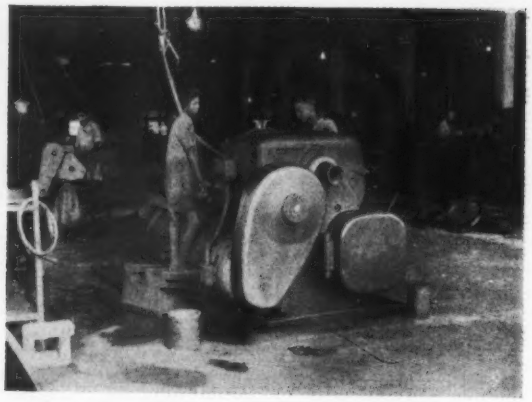


Fig. 7.—A View of Machines in the Machine shops occupying total floor area of 11500 SFT with 51 Machines

2. Stripping and inspection section.
3. Sub-Assembly bays like :
   (*i*) Valve grinding, (*ii*) Cylinder head section.
   (*iii*) Electricl accessories section, (*iv*) Supercharger blower, air compressor and pneumatic accessories section
   (*v*) Clutch and water pump, and
   (*vi*) Rocker Arm and Housing section.
4. Assembly bays—separate for each make, e.g. :—
   (*i*) Cummins engines (*ii*) Caterpillar engines.
   (*iii*) Hercules engines (*iv*) Buda engines.
   (*vi* General Motors engines (*vi*) International engines.
   (*vii*) Miscellaneous engines

A brief description of the flow of work in the repair shops is given below :

On receipt of a machine for overhaul, the engine is dismounted from the chassis and is brought to the de-greasing and cleaning section. After being cleaned by the steam jenny, it is stripped and all its sub assemblies such as cylinder heads etc. are passed on to the different sub sections named above. The engine is further dis-assembled and an inspection of pistons, piston rings, connecting rods, crankshaft, camshaft and housings etc. is carried out in the inspection bay. Inspection sheets are prepared giving micrometer readings of different parts and observations recommending rejection or otherwise of the parts are recorded. The sub-assemblies passed on to the different sections are treated likewise in each section and after being stripped they are reassembled by replacing parts, repairing them or cleaning and refitting them. These sub assemblies are later passed on to the assembly bays, each dealing with a different make of engines. Each type has got specially trained groups of workers working on them. The assembled engines are then 'run-in' on a test bed. The peformance of diesel engines repaired and overhauled in the shops has been quite satisfactory.

To ensure observation of specification etc. laid out by manufacturers in respect of each make and type of engine, specification charts (blue-print copies) are displayed at suitable places in the assembly bays. This helps the workmen to observe rigidly the limits,

(*Continued on page* 98)

Design of Canal Structures: Some features of the Major Aqueducts

By

S. BABINGTON, B.A., B.E., A.M.I.E.

Executive Engineer, Mahanadi Canal Circle, Hirakud Dam Project

AUTHOR

It is of interest to note that while the main dam of the Hirakud Project was designed by the Central Water and Power Commission, the canal structures were designed by the Hirakud Project's newly created department of designs. The following contribution gives an outline of the main features of the major canal structures such as the Regulators, Outlets, Falls, Aqueducts, Superpassages, Level Crossings and Road Crossings.

In this article, an attempt has been made to bring out in a general way the important aspects of the design of structures in the Hirakud Canals.

Canal structures are those necessary for the Canal System apart from the earthen waterway itself and its lining. They may be classified as under :

1. Works for controlling canal water.
   - (*a*) Regulators or Sluices.
   - (*b*) Outlets or escapes.
   - (*c*) Falls of drops.
2. Drainage Crossings.
   - (*a*) Aqueducts ; Syphon Aqueducts ; Drainage Syphons and Under Tunnels.
   - (*b*) Superpassages and Irrigation Syphons.
   - (*c*) Level Crossings.
3. Road Crossings.

Regulators

To control the quantity of water admitted into a channel, at the head of each is provided a bridge-like structure spanning the waterway, in the openings of which are installed shutters capable of adjustments. This is called a Regulator. Regulators are constructed mostly at right angles to the parent channel. In the case of the head regulators of the main canals taking off from the reservoir, the waterway provided is such as to enable the canal to draw full supply at the lowest water level of the reservoir. For smaller Distys. and Minors, the regulators are designed to draw full supply when the parent channels are running at half supply. When the difference in level between the F.S.Ls. is less than 3″, a minimum of 3″ 'cut off' is assumed for calculating the velocity and hence the waterway. The relationship $Q=5\ A\sqrt{h}$ has been adopted to determine the required waterway.

When the discharge is high, i.e. more than 20 cusecs masonry barrels covered by R.C.C. slabs or masonry arches have been adopted. (Fig 1). At the entrance, the head wall is carried by a R.C.C. lintel, the invert of which is adjusted to give the required area at F.S.L. of the off-taking channel. The height of the tunnel is kept a foot or so more than the vent opening. For discharges below 20 cusecs Hume pipes have beed adopted. The pipes are laid on a light concrete foundation 6″ thick to prevent uneven settlement and consequent leakage. These pipes are depressed where necessary upto a depth of 0.25d in order to make available the necessary waterway. In the case of outlets from canals distributaries and minors, the sill level and head for design are adopted as indicated in the chart below :

F.S. Depth in Canal or Disty	*Sill of outlet above Canal bed*	*Head for design of pipe*
8.0′	3.0	1.25′
7.0	2.5	1.25
6.0	2.0	1.00
5.0	1.5	0.75
4.5	1.25	0.75
4.0	1.00	0.75
3.5	0.75	0.50
3.0	0.50	0.50
2.5	0.25	0.50
2.0	Nil	0.25
1.5	Nil	0.25
1.0	Nil	0.25

Wing walls and floor are designed to secure a percolation gradient of 1 in 4. In the case of very small outlet sluices wing walls are not provided. A 12′ wide roadway is provided on the top. There are vertical grooves in the piers and abutments for the shutters to move up and down. The shutters are of wood or steel and are worked by screw gearing, when the F.S.D. of the parent channel is 2′ and above. For smaller channels, stem shutters with arrangements for locking them with padlocks are adopted. The maximum span adopted is 8′. The thickness of wooden shutters is kept 4″ for spans of 6′ and above, 3″ for spans 4′ and above but less than 6′, and 2″ for spans below 4′.

Escapes

Any large canal must for safety be provided with a number of escapes in order to discharge any surplus water or to quickly empty the canal in the event of a breach or a threatened breach. An escape is either a surplus weir when it is discharging from a level

above ordinary F.S.L. of canal or a surplus sluice when it is to discharge down to the level of the sill. In the case of the Main Bargarh Canal, two shuttered escape sluices with capacity equal to the full canal discharge have been provided above two major aqueducts, the approaches to which are in very high banking. These escapes are combined with a cross regulator on the main canal for obvious reasons.

The Sason canal is carried in single bank between R.D. 12,000 and R.D. 15,000 where it skirts around the foot of a hill. The unbanked lengths form practically continuous surface inlets. To dispose of the water so received an escape weir has been provided with capacity equal to the full discharge of the catchment intercepted by the canal. The Sambalpur Distributary passes through 3 tanks and in these places escapes have been provided on the same lines for a similar reason. The discharge from the catchments of two tanks is high compared to the discharge in the distributary and in these places escape sluices with shutters have been provided facilitating complete emptying of the canal and removal by scour any accumulation of silt in the canal bed in the vicinity. (Fig. 2).

Escape at R.D. 20500 of Sambalpur Distributary

Distributary	*Tank*
Bed level 565. 94	Catchment area 20 acres.
Bed width 13 ft.	High flood discharge 59 cusecs.
F.S. Level 569.15	
F.S. Discharge 93.9 cusecs	N.S.L=572.06

As suited to site conditions bed of escape is scraped upto 568.40. Crest of weir is kept 569.15.

Depth of Water over weir=9″
Hence length of weir $=59/3.09\times0.75^{3/2}=29.4$
Length of weir provided 30 ft.

Foundation of drop wall is taken 2′ below deepest drain level. Banks on either side of escape are strengthened by 9″ extra height for a length of 5000.′ Impervious aprons and suitable bank connections are provided on usual lines to protect against percolation and uplift.

Falls or Drops

Where the natural slope of the country over which the canal passes is greater than the safe grade of the canal it is necessary to transfer the canal safely from a higher level to a lower level by providing suitable structures wherein the excess grades are concentrated. Such structures are termed "Drops" or "Falls". They are either "vertical" or "inclined." In the case of the main canal there are no major drops as it is running on contour. But in the branches, distributaries and minors drops are necessary and have been provided.

The type of falls adopted for different discharges and falls are as below :

Discharge	*Fall*	*Type adopted*
50 cusecs and above	4′ and below	Vertical
50 cusecs and above	Above 4′	Glacis and notch.
Below 50 cusecs	6′ to 13′	Well type
30 cusecs to 50 cusecs	4′ to 6′	Glacis and notch.
10 cusecs to 30	4′ to 6′	Skin type and notch type
Below 10 cusecs.	Upto 6′	Rubble cascade.

Vertical Type—Constructing a 3′ fall at RD 18360 of Parmanpur Distributary. (Fig. 3)

Canal	*U/s*	*D/s*
F.S.L.	564.00	561.00
B.L.	560.80	557.80
Discharge	112.59	104.55
B.W.	14.0	14.0
F.S.D.	3.2	3.2
N.S.L.	566.3	—

Vertical type of falls are unflumed.
Depth of flow over the crest is calculated from formula $Q=3.3\times L\times h^{3/2}$. $Q=3.325\times B\times D^{3/2}(D/L)^{1/6}$ is also used.

$$\therefore h=\frac{(104.55)}{(3.3\times14)}=1.72$$

Crest level=564.00—1.72=562.28

$$\text{Depth of cistern}=\frac{Hx+D}{3}=\frac{3.0+3.2}{3}=\text{Say } 2'$$

(Depth of cistern is also given by $1/6\ (Hx\times h)^{2/3}$
∴Cistern level=557.8−2=555.8
Length of cistern $=5(Hx\times D)^{1/2}=5(3\times3.2)^{1/2}=15.51$
say=15.50
Top width of drop wall $=\sqrt{h}$
Generally 2′ top width has been adopted.
Bottom width of drop wall
=0.5(564.0−555.8)=0.5× 8.2=4.1′ say=4′ 3″.

Thickness of the solid apron in the cistern is maximum under the drop wall and is reduced gradually at the other end. Calculations are made considering it in 3 portions.

For a distance of 1/3 L thickness provided
$=0.35\times D_1=4.48\times0.35=1.56$ Say: 1.75′
Middle 3rd length $=0.2\times D_1=0.896$ say: 1.25′
Remaining portion $=0.1\times D_1=0.448$ say: 1.0
(D = height of crest above cistern level)

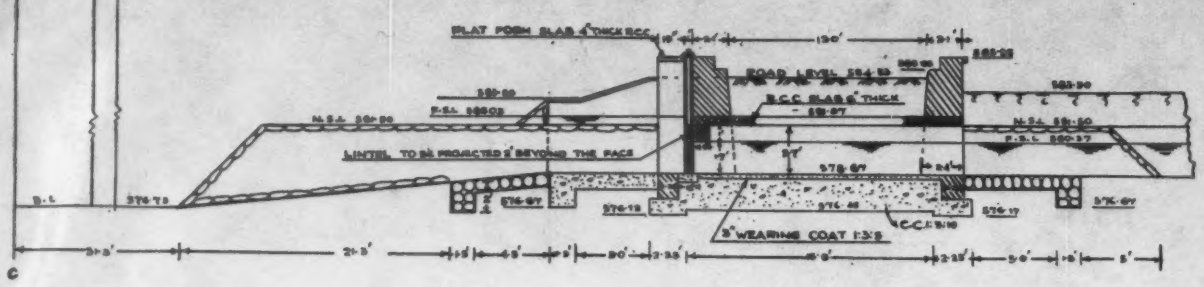
Masonry bank connections are of the wing type. In the U/s side curved wings are provided, the curve being tangential to the sides at the crest. The wings are taken 2′ inside the bank at the U/s end. From the drop wall to the end of the cistern the wings are carried straight and returned at the end generally at right angle and at times with a splay of 45°, as suited to the site. The walls are 1.5′ thick at top and 0.4H thick at bottom, with face vertical. Thickness of concrete under walls is 2.0′. The foundations of the wings are stepped as ground permits.

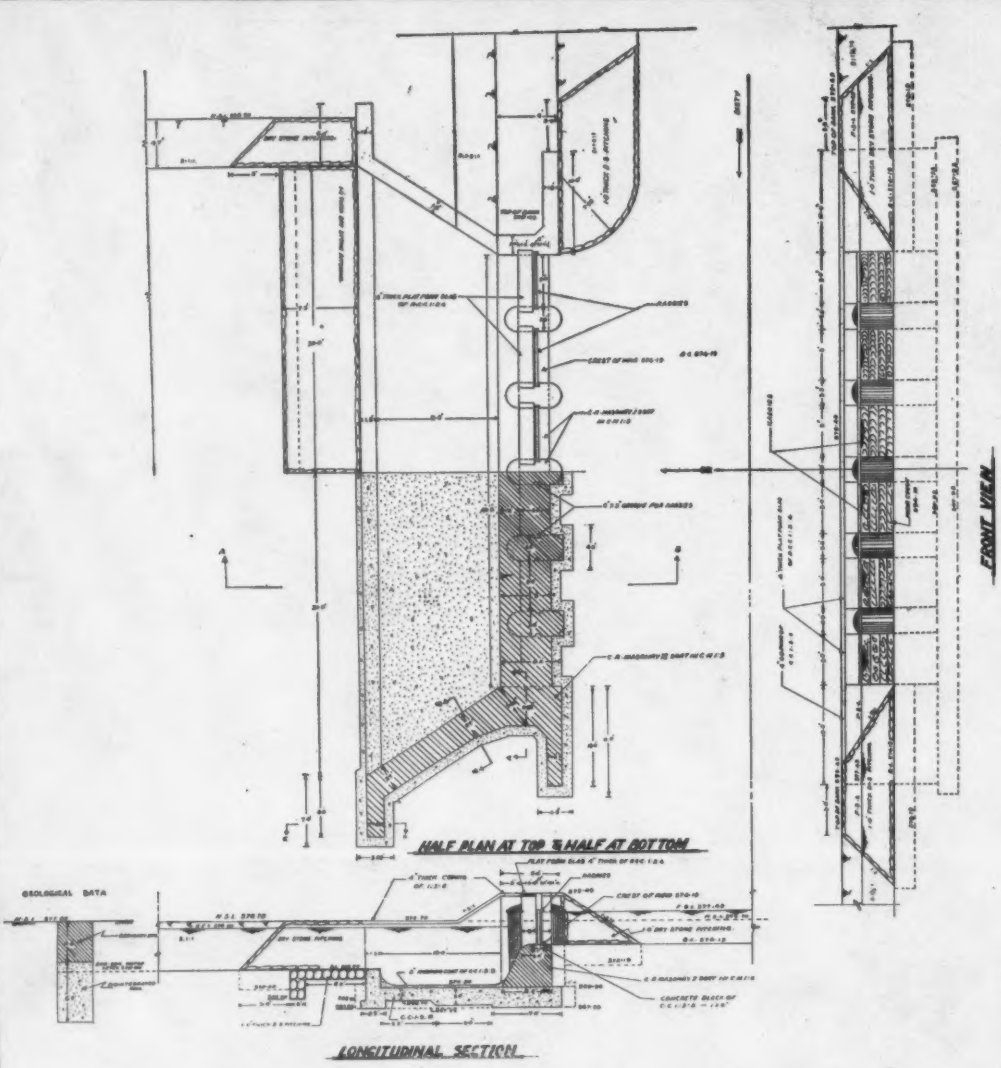
At the end of the cistern a toe wall with 1.5′ top width is provided, the foundation of which is taken about 3″ to 6″ blow the apron concreting. Beyond the cistern, bed pitching is provided for a length of $3\times D$ and revetment on side slopes extends for a further length = 3D. In the U/s side the bed pitching is 5 times the height of crest over the bed and the revetment extends an equal length beyond.

HEAD SLUICE AT R.D 9910
ATTABIRA BRANCH
SCALE 1:8

HYDRAULIC PARTICULARS

DESCRIPTION.	BRANCH.	DISTRIB
F.S.D.	250 Cs.	20
F.S.L.	582.03	580
BED LEVEL.	576.73	576
F.S.D.	3.30'	1
BED WIDTH	63.0'	5
BANK WIDTH.	60/16'	4
FREE BOARD	2.5'	1
T.B.L.	584.83	58



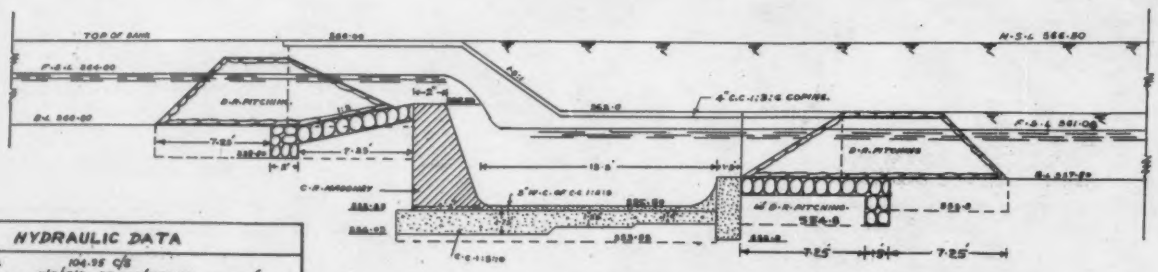


ESCAPE AT R.D. 9900 OF SAMBALPUR DISTRIBUT
SCALE 1"=5'

HYDRAULIC DATA

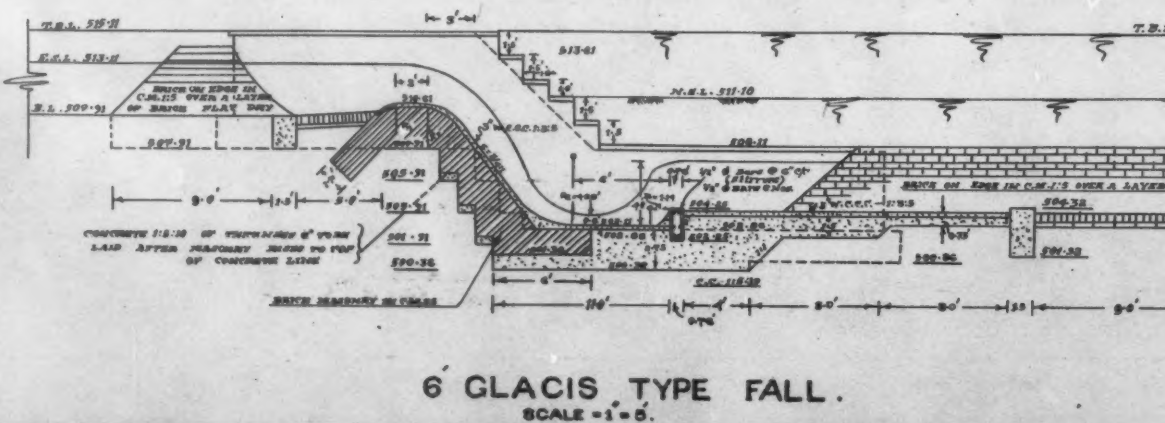
CANAL		ESCAPE	
F.S.D.	145 C/S	C.M.BM.	1:2:4
F.S.L.	577·40		
B.L.	574·13	F.S.D.	0·50 C/S
F.S.D.	4·0'		
BED WIDTH	70·0'	M.F.L.	580·0
FREE BOARD	2·0'	M.B.L.	578·17
BANK WIDTH	6/6'		

3' VERTICAL FALL
AT R. D. 18360 OF PARMANPUR DISTY.
SCALE = 1"=5'.

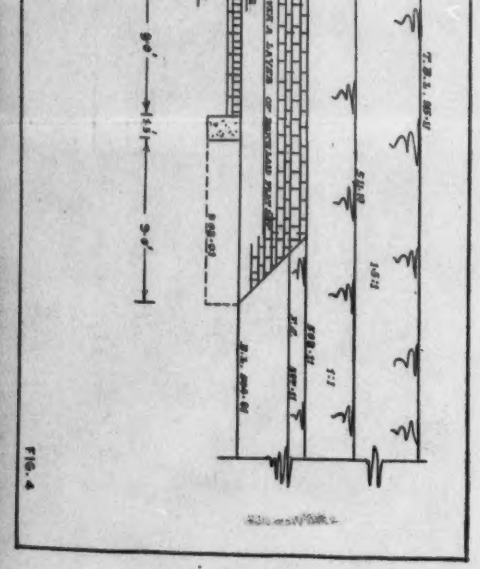


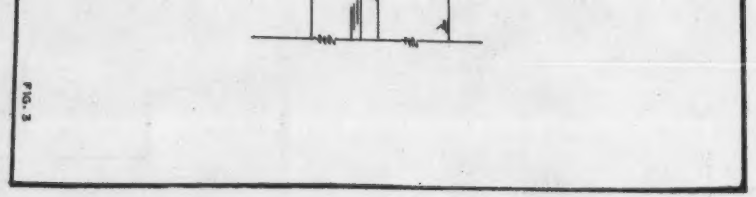
HYDRAULIC DATA

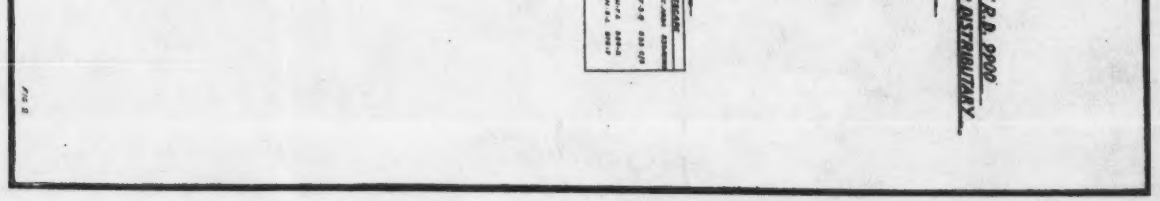
F.S.Q.	104·95 C/S
F.S.L.	U/S 584·00/581·00 H= 2·6
B.L.	580.8/577.80
F.S.D.	3.2'
BED WIDTH	14.0'
M.S.L.	586·30
FREE BOARD	2.0'
BANK WIDTH	6/6

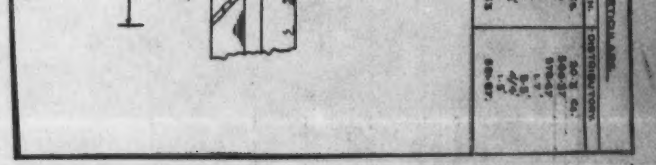


6' GLACIS TYPE FALL.
SCALE = 1" = 5'.

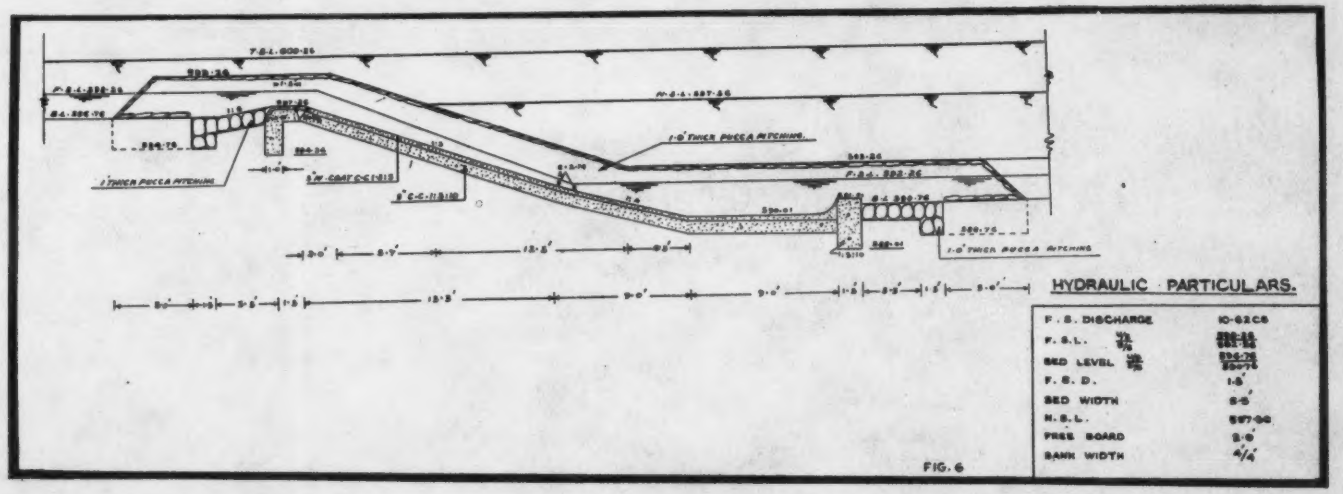




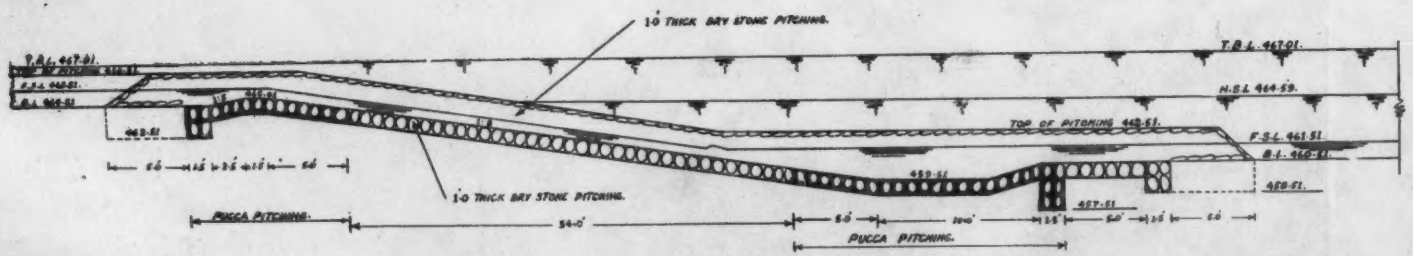




6′ SKIN TYPE FALL AT RD 192250 OF HOMA DISTY.



4.0′ RUBBLE CASCADE FALL OF HOMA DISTY.



DATA

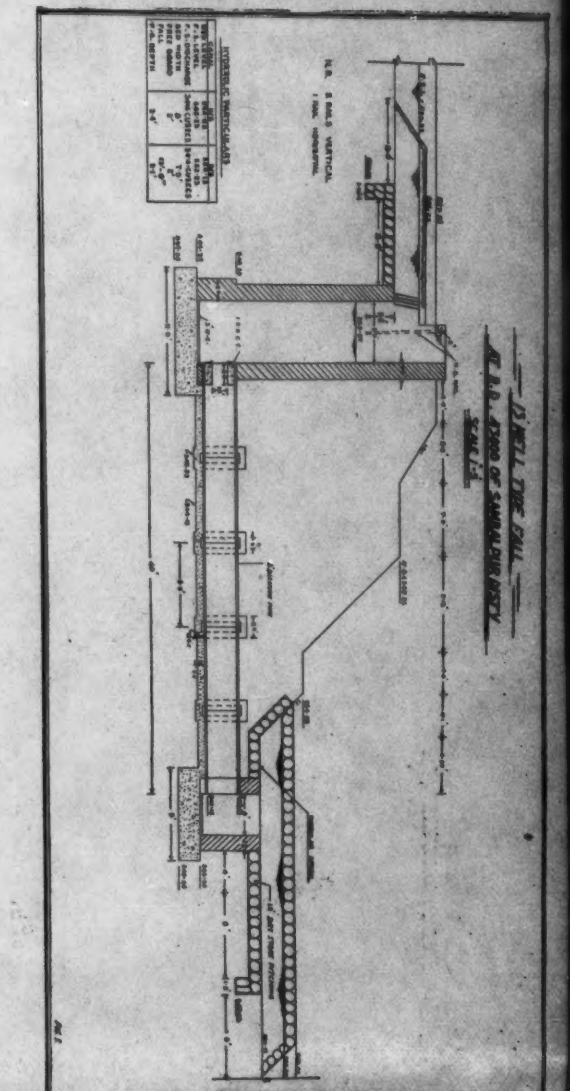
	U/S	D/S
F.S.DISCHARGE	3.52 CS	
F.S.L.	461.51.	461.51
B.L.	456.51.	456.51.
F.S.D.	1.0'.	
BED WIDTH	5.5'.	7.5
FREE BOARD	1.5'.	
BANK WIDTH	3.0	3.0
H.S.L.	464.59	464.59

$H = \left(\frac{3.52}{3.09 \times 5.5}\right)^{2/3} = 0.975$ SAY 0.5'.

S.C. CREST LEVEL = 461.51 - 0.50 = 461.01

CISTERN 3.0' BELOW D/S B.L. = 453.51.

CISTERN LENGTH = 10.0'.



Notch Type

Falls with a single notch or multiple notches have been adopted. The designs are of the Ellis pattern discussed in the Manual of Irrigation by Col. W.M. Ellis.

Glacis Type (*Fig.* 4)

On economical considerations, the bed is flumed to 67%. The depth over crest is derived from the same formula $Q=3.33 \times L \times h^{3/2}$

The U/s glacis is kept 1:1 while the D/s glacis is $\frac{3}{4}$:1. The baffle platform is kept at a depth d x below D/s water level where $dx = 0.75\ q_c^{0.52}\ H_x^{0.21}$. The height of the baffle hb = dc—dz where dc is the critical depth calculated from the formula $(q^2/g)^{1/3}$ and dz is the depth of flow in the baffle platform at toe of face, read from a graph connecting Hx and dz or from the equation $dz = 0.11q^{0.89} \times H_x^{-0.35}$. The width of the baffle wall is kept as 2/3 hb. The length of the baffle platform is 5.25(dc—dz). The cistern below the baffle is kept at the same level as the D/s bed level and its length kept as 5dx. The deflector at the end of the cistern is a cement concrete wall $1\frac{1}{2}'$ wide taken 3′ below D/s bed level. It projects above the D/s bed level by a height equal to $\frac{d_3}{10}$ where d_3 is the full supply depth downstream.

Pavement thickness in baffle platform is $0.35D_1$ where D_1 is the height of crest above the baffle platform. Pavement thickness in cistern is worked out as below :

First	1/5 length	$=0.35 \times D_1$.
Middle	2/5 length	$=0.2 \times D_1$.
Last	2/5 length	$=0.1 \times D_1$.

The bed pitching and revetment above and below and wing walls are as for the vertical type.

Well Type (*Figure* 5)

This type of falls consists of an inlet well with a suitable pipe in the bottom leading to a cistern or a downstream well with circular apron. The D/s well is necessary in cases of falls above 6′ and discharge over 10 cusecs. To increase the loss of head, additional contraction is provided at the entry into the pipe. Water falls into the well through a notch in the well steining, designed on the Ellis pattern.

13.0′ *fall at R.D.* 43000 *of Sambalpur Distributary.*

	U/S	*D/S*
Bed Level	562.83	550.13
F.S. Level	565.23	552.23
F.S. Discharge	34.4 cusecs	34.4 cusecs
B.W.	8.0 ft.	7.5 ft.

Notch

Full supply condition.

$3.74 \times 2.4^{3/2} \times (1+0.4 \times 2.4n) = 34.4$

At half supply, $3.74 \times 1.8^{3/2}(1+0.4 \times 1.8n) = 17/2$

Solving L=1.26 Say : 1.25 ; n=0.89

$\therefore \text{Tan}^a$ =0.44 Say 2 in 1

So that width at bed =1.25 and width at F.S.L. =3.65

Velocity in the notch $=\frac{34.4}{5.76}$ 5.9′/Sec (V)

Adopting a 3′ dia. pipe, velocity in pipe $=\frac{34.4}{7.07}$ =4.85′/Sec. (V_1)

Velocity in the opening of 1.5′ dia. pipe $=\frac{34.4}{1.76}$ =19.6′/Sec(V_2)

Level of water in well = H.F.L. $D/S + \frac{0.5V_1^2}{2g} + \frac{V^2}{2g}$

$$+\frac{(V_2-V_1)^2}{2g} + \frac{V_1^2N^2L}{1.486^2R^{4/3}}$$

$$+\text{Loss in D/S level } \frac{(V_3^2)}{2g}$$

=552.23+3+0.36+3.35+0.16+0.17=559.27

Centre of pressure is at=562.83+0.8=563.63.

Hence the 'Y' coordinate of falling water is 563.63−559.27=4.36.

Hence $= V\frac{1X}{\sqrt{\frac{2y}{g}}} = 5.9\ \sqrt{\frac{2\times 4.36}{32.2}} = 3.02$

Hence diameter of U/S well should be $3.62+\frac{4\times 2.4}{9}$ or 4.07

Adopt 5′ well U/S and 4′ dia. well D/S. Provide 1′ of water cushion in the bottom of U/S well. Wells will be 1.5′ thick if in stone and 1.7′ if in brick masonry. Foundation concrete under well will be 2′ with 3″ wearing coat of cement concrete 1:3:5. The pipes will be laid in a bed of concrete 1′ thick ; this is increased to 15″ under collars provided for the joints. Revetment in bed and sides will be of dry stone for a length 3d in both U/S and D/S sides subject to a minimum of 5′.

Skin Type (*Figure* 6)

This is an inclined fall. The ground is cut to a flat slope with necessary cover over the saturation line of 1:4 and a hard skin is provided over it. The skin is of 10″ brick masonry or 9″ thick cement concrete (1:5:10) with 3″ thick wearing coat of cement concrete 1:3:5. The U/S glacis is kept 1:5 while the D/S glacis is kept 1:3 upto D/S F.S.L. and then 1:4 upto the cistern. The cistern level will be 1.25 dx below D/S F.S.L. and of length 5 dx. The deflector 1.5′ wide and taken 3′ below bed level, projects 0.25′ above D/S bed level. The sides are reveted upto 1′ above F.S.L. all along the fall. The bed width in structure is flumed to about 67%. The crest of the fall is kept 1.5′ and height 'h' over the crest is calculated from $Q=3.33 \times L \times h^{3/2}$ Pucca pitching extends upto 5h in the upstream. In the D/S dry pitching and revetment extends as usual.

Rubble Cascade. (*Figure* 7)

This is the simplest type of falls and is merely dry rubble packing 1′ thick in bed, pavement as well as sides. The slope adopted is 1:8. The crest is kept 1.5′ wide and the depth of flow 'h' over it calculated from the relationship,

$$Q=3.09 \times L \times h^{3/2}$$

U/S glacis is kept as 1:5. The cistern level is kept 1.0′ below D/S level and it is 10′ long. At the end of

the cistern a concrete toe wall 1.5′ wide is taken 3′ below B.L. The bed pitching and revetment inside are as in the previous cases. The pitching is made pucca for a length of 10′ to 15′ including the crest in the top, and for a length of 15′ to 20′ including the cistern in the bottom.

Where there ia a cart track or a village road near the proposed site of a fall, a bridge has been combined with the fall if it is any of the types other than skin and rubble cascade. The bridge is generally provided in the D/S side by extending the solid apron straight to the required length. In the case of the well type, an extra pipe or two is sufficient to provide the roadway on top.

Cross Drainage Works.

Numerous drains of all sizes are intercepted by the canals, distributaries and minors. Especially the main canals running on contour have to cross many drainages in their alignment. The methods adopted for disposal of the drainage so intercepted are:

(1) To carry the canal over the drainage channel by means of an aqueduct or a syphon aqueduct or a drainage syphon.
(2) To carry the drainage over the irrigation channel by means of a superpassage or a canal syphon.
(3) To divert it to the nearest drain if the drain is small and if the intervening ridges are not high.

In every case the method adopted and the structure provided have been decided only after careful study of the detailed site plan of the crossing (Scale 1″= 50′) along with particulars regarding trial pits, maximum flood discharge, availability of building materials etc. The location of the major structures have been suitably adjusted, after inspection in the field, to obtain square crossings, better foundations, easier approaches and exits etc. The maximum flood discharge for larger catchments have been computed with a co-efficient of 1060 in Dicken's formula $Q=CM^{3/4}$ where M is the area of the catchment in square miles. This co-efficient is being adopted by the Orissa P.W.D. and floods during 1955 which were one of the biggest in recent years justified its adoption. For catchments below 5 square miles the discharge is read from a curve based on an intensity varying from 3 cusecs per acre for a few acres, to 2 cusecs per acre for 1 sq. mile and 1.1 cusecs per acre for 5 sq. miles.

Aqueducts

When the bed level of the drainage is well below the grade of the canal the latter is carried across in an Aqueduct. When the drainage bed and the canal bed are near about the same, the bed level of the drainage is dropped where it passes under the canal, so that the drainage passes through an inverted syphon and this work is termed as a 'Syphon Aqueduct'.

Where the drainage crossed is large, 25′ span aqueducts have been provided with independent foundations for piers and abutments. Where the drainage crossed is medium sized and if hard strata is met with a reasonable depth below the drainage bed, 10′ span aqueducts have been adopted with a paved floor, which also forms the foundation of the structure. Where the channel discharge is very small, pipe aqueducts have been provided.

The Major Aqueducts

The Main Bargarh Canal crosses four small rivers namely Danta, Girsul, Jira and Ranijhore.

The conditions prevailing in the crossings over the first three being similar a common design has been adopted.

Girsul Aqueduct (Figure 8a)

Data

Discharge		*Canal*
Catchment area	98 sq. miles.	Bed width 110 ft.
Discharge	33000 cusecs	Discharges 3145 cusecs.
Bed Level	549.00	B.L.in trough 567.71
M.F.L.	557.6	F.S.L. 577.61

Waterway 17 spans of 25′ 4 compartments11′-3″ wide.

The large head room available above the H.F.L. of the drainage has been advantageously utilised by keeping the trough bed lower than the theoretical bed level of the canal. This gives a greater depth of flow and consequently smaller width of trough and piers. In this case bed is depressed by 1.6′ inside the trough. Lowering of bed upto 25% of F.S.D. has been adopted in other cases. The flumed bed width in the trough is fixed by adopting a velocity about double that of the canal. The flow conditions are checked as below:

$$\text{Velocity in the canal} = \frac{3145}{110 + 4.45} = 2.74 \text{ ft/sec.}$$

$$\text{E.f.} \quad d + \frac{V^2}{2g} = 8.9 + 0.117 = 9.017$$

The bed has been lowered by 1.6 ft. and so neglecting losses Ef=9.017+1.6=10.617.

$$Q \text{ inside trough is} \frac{3145}{45} = 69.89$$

Depth of flow in trough =9.9
and flow is subcritical. (*Plate* IV *CBI Publication* 4)

The co-efficients for entry and exist losses are taken as 0.1 and 0.2 respectively of the difference in velocity heads. The head lost in the trough is calculated as per Mannings formula. The loss of head in the approach flume is not considered since the flumed section will be able to carry the full discharge with the designed slope of the canal. The total losses so calculated is within 0.2′ in the case of all the 3 aqueducts

The maximum flood discharge is computed on the basis of Dickens formula $Q=1060CM^{3/4}$. The catchment areas are computed from 1″: 1 mile map. The number of spans provided are such that no encroachment in the existing waterway is made and the drainage has been left severely alone. The abutments are placed well on the bank on high ground and the end piers rest on the side slopes of the drainage thereby forming a land span on either side. In the river bed sand is met with to a depth of 20′ and hence well foundations have been adopted. The wells have been taken upto 20′ below summer water level which is virtually the bed of the drainage itself.

Good granite stone is available within 3 miles lead and hence coursed rubble masonry in cement mortar 1:4 for piers and 1:5 for abutments etc., pointed in the outside with cement mortar 1:3 has been

adopted. The canal water is carried in a R.C.C. trough of mix. 1:1½ :3. The trough is divided into four compartments with the partition walls acting as beams. In the 3 open compartments the beams are connected at the top by stiffeners. The roadway is carried over the left end compartment which is covered by a road slab designed for 'B' class loading. The approaches to the aqueduct are flumed and lined with the cement concrete 1:3: 5 reinforced with ¼″ diameter bars at 6″ intervals running in both directions. A double set of wings are provided ; the canal wings for making a staunch connection between the side walls of the aqueduct and the canal banks and the drainage wings for retaining and protecting the earth slopes and forming guide walls to the water entering and leaving the work. To protect them from scour dry stone pitching is provided along the abutments, wings and return walls. The top horizontal portion of the revetment is kept 1′-0 above H.F.L. and 10′ wide ; this is used as a subway. There is also a foot bridge across the aqueduct on the top.

Structural details.

The side walls as well as bottom slab which are to carry water will be of 1:1½ :3 C.C. to ensure water tightness without any special water-proofing. The working stresses adopted for members coming in contact with water are C=700 ; t=12000, m=12, n:0.412 d, M :124 bd², AS : 0.12 bd, a : 0.863 d.

Road slab, bearing slab under girders and other portions not in contact with water will be of 1:2:4 C.C. The working stresses adopted are C=750, t=18000; m=15, n=0.38 d, AS=0.008bd: a=0.872d.

The trough has four compartments 11′-3″ each running a maximum depth of 11′ 3″ in the Danta Aqueduct and 9″ less in the Girsul and Jira Aqueducts. The trough is designed for the maximum depth of water. If the lift canal requiring 980 cusecs, originally proposed and deferred for the present, is abandoned for good, three compartments will be sufficient.

The bottom slab is rigidly attached to the beams by rigidity rods and the ends are taken as fixed. Thickness of slab is calculated by taking moment as WL/12 and it works out to 10½″. At the junctions extra thickness is provided to prevent cracking due to negative BM=45 bd². A splay of 9″ vertical and 12″ horizontal at junction of slab with beams has been provided and necessary splay rods are provided (Figure 8 (*b*) and 8(c).

As already stated the partition walls function as beams and carry the water load and dead weight of the trough. The beams under the roadway carry the live load on road slabs as well. The effective span is 27′ and depth of the beam is 12′ 6″ plus 10½″ or 13′ 4½″. Main reinforcements are provided at the bottom in 2 or 3 tiers of 3 rods of which 3 rods of top tier have been bent up. One set of 2 rods is used at the top to provide lateral rigidity and to serve as stirrup hangers. To take up the extra shear near the ends 3/4″ U shaped stirrups are provided at suitable intervals. These stirrups go around the main reinforcements and are hooked to the stirrup hangers at top. The beam has been tested as a cantilever wall for water pressure and cantilever reinforcement provided. The rods for cantilever reinforcement are bent around the main reinforcement so that they will serve as shear stirrups mentioned above. These stirrups will also take any secondary bending moment on the outside due to partial fixture at the top from the distance pieces and road slab. The road slab has been designed for 'B' class loading and it is found that a 10½′ thick slab is sufficient. Distance pieces of section 8″×10½″ reinforced with 3 Nos. ½″ diameter rods at top and bottom at 8′ 3″ centres have been provided to give lateral rigidity to the trough. At the transition from the trough to the approach bank the road is carried over a triangular slab supported on a parapet girder at one end and the canal wing on the other.

The beams rest on 2′ thick R.C.C. bed blocks that distribute the load on the masonry below. The safe bearing pressure on stone masonry has been taken as 6 tons per square foot. The reinforcements have been designed to suit the stresses developed by the loads under each beam. The trough is held down to the pier by holding down bolts on alternate piers. On these piers construction joints with copper plate and bitumen filling is provided. On the other piers expansion joints of copper plate with bitumen filling is provided. These copper plates run round the trough in the outside walls and bottom slab only. The partition walls do not have copper joints.

The top width of piers and abutments is kept as 4 ft. the safe load allowed on stone masonry being 6 tons per sq. ft. The piers are finished in two footings to 6′ base width the top 10′ being kept 4′ wide and the balance height kept in two footings of equal height. The abutments have a face batter of 1:6 the required thickness in the bottom being made up by providing suitable back batter. The base widths of all abutments and wings of all the important structures were first fixed by Empirical formula B=0.3 to 0.4H and the stability of the section checked for the worst conditions. Earth pressure was determined by the pressure triangle obtained by Rebhan's Construction. Earth was assumed to be moist having a density of 125 lbs./cft, angle of repose taken as 35°. and coefficient of friction between earth and masonry assumed to be 0.25.

The piers and abutments and drainage wings rest on R.C.C. capping slabs which transmit the load to the octogonal wells placed below. The wells are placed in a row with 1′ clear distance between the parallel faces. The maximum gap between the wells is at the outer edge where the inclined faces widen the gap to about 4′. The capping slab is designed for this span as a continuous slab over the wells. The thickness adopted is 15″ with an extra 6″ counter sunk into each well so as to serve proper keying in of the slabs. Suitable reinforcements for negative B.M. and stirrups for taking up the shear are provided. The vertical rods from the well steining are taken into and anchored in the capping slab. Thus the capping slabs distribute the load equally to all the wells.

The sizes of the wells adopted under the piers, abutments and drainage wings were fixed to suit the base widths obtained. In all the three aqueducts, under the piers 7 nos. 8′ octogonal wells are provided with 1′ clear distance between them. For the abouments twin octoganal wells of sizes 16′×8′, 14′×8′ and

12′×8′ have been adopted to suit the different base widths. Under the returns, 8′ octoganal wells or 6′×6′ square brick wells are taken 8′.0 below capping slab level. The maximum scour depth is likely to extend below half the depth of the wells and so skin friction has not been taken into consideration. The pressure transmitted on to the foundations on the bottom of the well is 3.63 tons and it is well within safe limits for compact sand at 20 ft. depth.

The steining of wells is in cement concrete 1:3:6, 2 ft. in thickness. reinforced with one 3/4″ rod at each of the 8 corners and hoops at 2′ intervals. The pressure developed on the steining is about 5.5 tons at bottom which is within safe limits. The wells have an R.C.C. curb at bottom 2½′ high with an angle iron cutting edge. (Figure 8(*d*). The wells after being taken to full depth have been plugged at the bottom with rich concrete 1 :2 :4 for a height of 1½′ and then 3.5' with 1:4:8 C.C. The top plug excluding the counter sunk portion of the capping slab is made of 2.75′ of 1:4:8 C.C. The intervening space between the top and bottom plugs of concrete is filled with well compacted sand.

The Canal is carried in a lined flume for 250′ upstream and downstream of the trough. The lining is of cement concrete 1:3: 5, 6″ in thickness with ¼″ dia. bars at 6″ intervals running in both directions. Where the trough wall ends, the canal wing begins, forming the bank connection between the sides of the aqueduct and the canal banks. The canal wing has its face vertical near the trough but is changed to have face batter within a short distance of 8′ or so. The flumed width of the trough is continued beyond the trough for 250′ on either side. But the side slopes are gradually changed from vertical near the end of the trough to 1½ :1 at the end of the canal wing. The canal wings are carried straight for a distance of 20′ and then smoothly opened out in a reverse curve to accommodate the side slopes of the lined flume. The lined flume is transitioned to the normal canal bed width with a splay of 1:5 in the D/S and 1:3 in the U/S. The Canal wings are founded 2′.0 below N.S.L. Along with the drainage wings, the canal wings form the full bank connection retaining the earth slopes and acting as stop walls for percolation. The wings are designed by making a plan showing the canal banks, stream margins and earth slopes. It is seen that the minimum length of percolation for a hydraulic gradient of 1:4 is provided and if not wings are extended suitably. The canal wings extend to about 80′ beyond the abutment. As bed protection to the canal, a solid apron of cement concrete is provided between the abutment and the toe wall at the end of the canal wings, and over this the lining is laid.

Aqueduct over Ranijhore

at R.D. 203400 *of Bargarh Canal. Figure* 9(*a*)

Canal		*Drain*	
Discharge	1650	Discharge	31600
Bed width	98/30	Bed width	340
F.S.L.	563.13	H.F.L.	538.00
B.L.	557.69	B.L.	527.13
	552.63		
F.S.D.	6.4	H.F.D.	10.87
	10.5		
Waterway	30.0	10 spans of 25	
N.S.L.	537.0		
Catchment area		95.2 sq.miles.	

By providing 10 spans of 25′ both the abutments are located on high ground. At the site of the structure rock level is fairly high and so open foundations have been adopted. All round the piers and abutments 1.5′ thick stone pitching is provided to safeguard against opening of the foundations by scour. Since the head room available is quite high water is carried at a greater depth in a masonry trough on concrete arches The thickness of the arch is calculated from $0.5\sqrt{R}$ say 2.0′. Concrete used is 1:3:6 c.c. The haunch filling is of cement concrete 1:5:10. The trough side walls designed as gravity type retaining walls, are of coursed rubble masonry in cement mortar 1:4 plastered in the inside and pointed on the outside.

The piers and abutments have been designed on empirical rules and tested for stability. The 3rd and 7th piers have been designed as abutment piers. It is worth while to point out that the base width of the abutment piers is more than the abutment itself as it has to serve as an abutment for either face and has no earth thrust to count upon for purposes of stability. (*Fig.*9(*b*))

The bank connections are exactly similar to those of the Girsul Aqueduct explained above.

Medium-sized Aqueducts (Fig. 10(a))

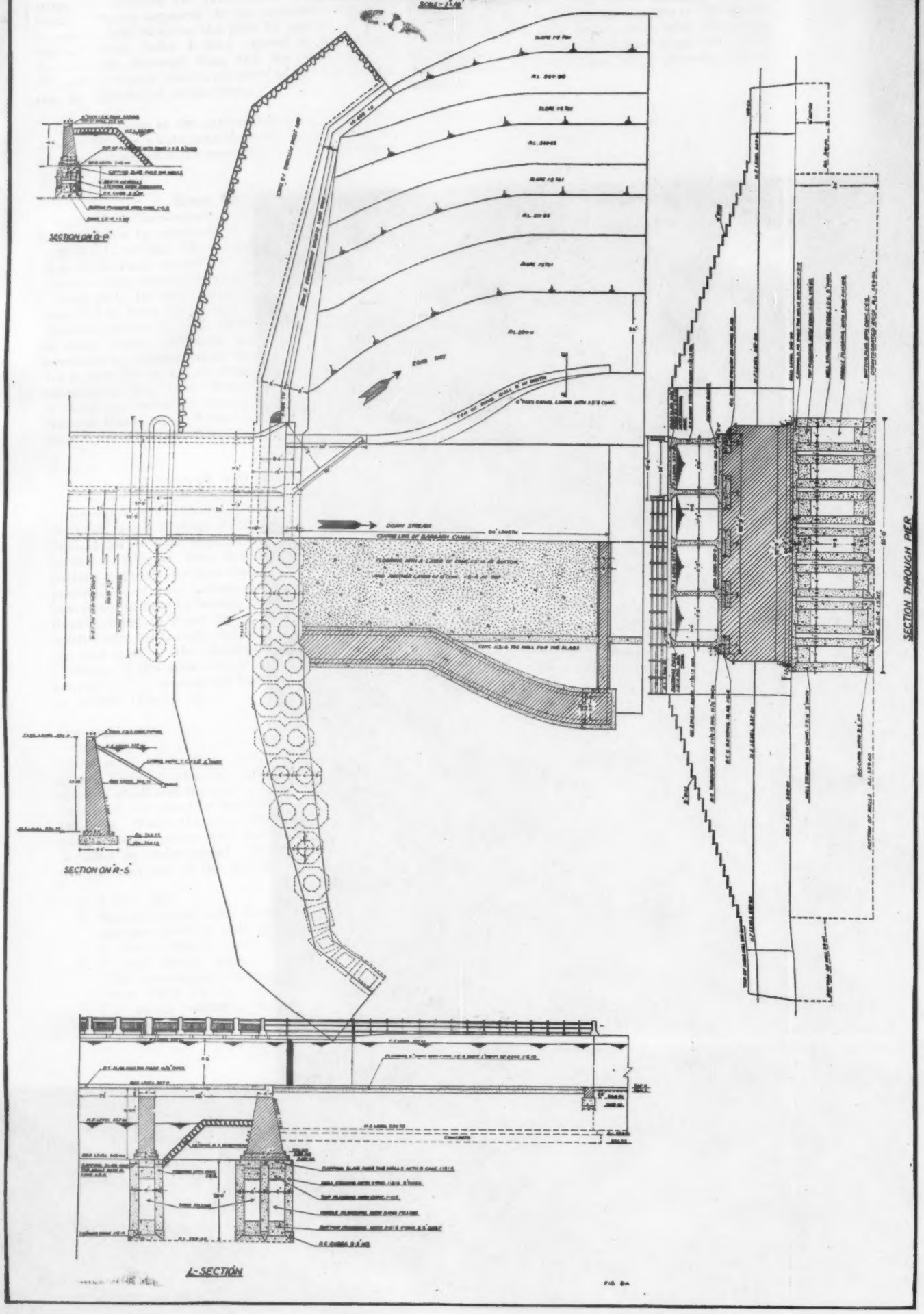
In the case of medium sized drainages, as already mentioned, 10′ spans are adopted. The foundation of the structure consists of a mass concrete floor 3′ thick inclusive of 3″ wearing coat, between the lift and drop walls. The lift and drop walls are taken down well below scour depth and founded on hard soil. The waterway adopted is such that the velocity of flow does not exceed 8′ f.p.s. at maximum flood. The tops of lift and drop walls and the floor are generally kept in the drainage bed level. In certain cases where the stream is shallow, the bed has been depressed between the lift and drop walls to increase the waterway. The drainage wings are splayed to the width of the tail and approach channels. The drainage returns upstream and downstream are kept 1′ above the calculated high flood levels, the U/S returns generally being 6″ to 1″ higher than the D/S returns due to the afflux required to carry the water through the culvert. To balance uplift a mass concrete floor of the requisite thickness is placed suitably on both the sides as apron. Dry stone pitching 1.5′ thick is provided beyond.

Trough is of R.C.C. The floor slab is designed to span over supports and the side walls are designed as cantilevers for lateral water pressure. (Fig. 10(*b*)). The bottom slab is designed as continuous slab over 2 or 3 spans with increased thickness over the support to take up the support moment, with the same steel used at mid span. Fig. 10(c). At the junction of the bottom slab and the side wall necessary splay is provided in the inside. The slab is checked for negative bending moment induced by the side cantilever, and tension induced on it due to the thrust on the side walls. The side wall is designed as cantilever and also as beam to carry its own weight. The distributors of the bottom slab are continued upward in the outer face of the side walls as temperature reinforcement. On the inspection path side a roadway 12′ wide is carried on a set of arches on piers extended to carry the same. Where the height is great the archway is over two spans i.e. 20 plus 3 or 23 feet span while in the low structures arches are of the same span as the

AQUEDUCT OVER GIRSUL AT R.D. 99700 (D/S SIDE) OF BARGARH CANAL

SCALE:- 1"=10'

SECTION ON Q-P

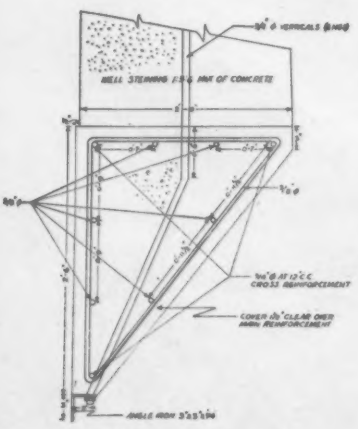


SECTION ON R-S

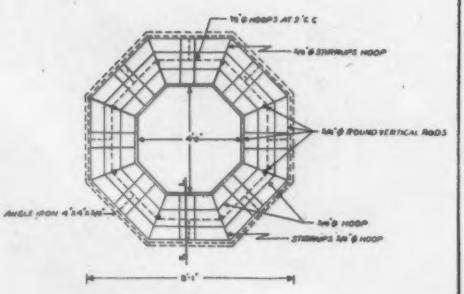
L-SECTION

DETAILS OF R.C.C. CURBS FOR GIRSUL AQUEDUCT

SCALE:- 2"=1'0"

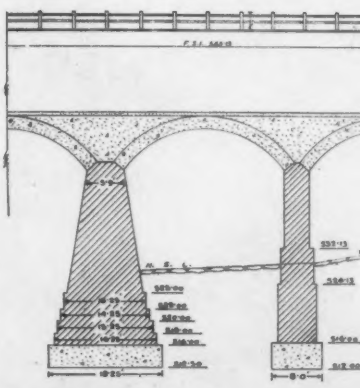


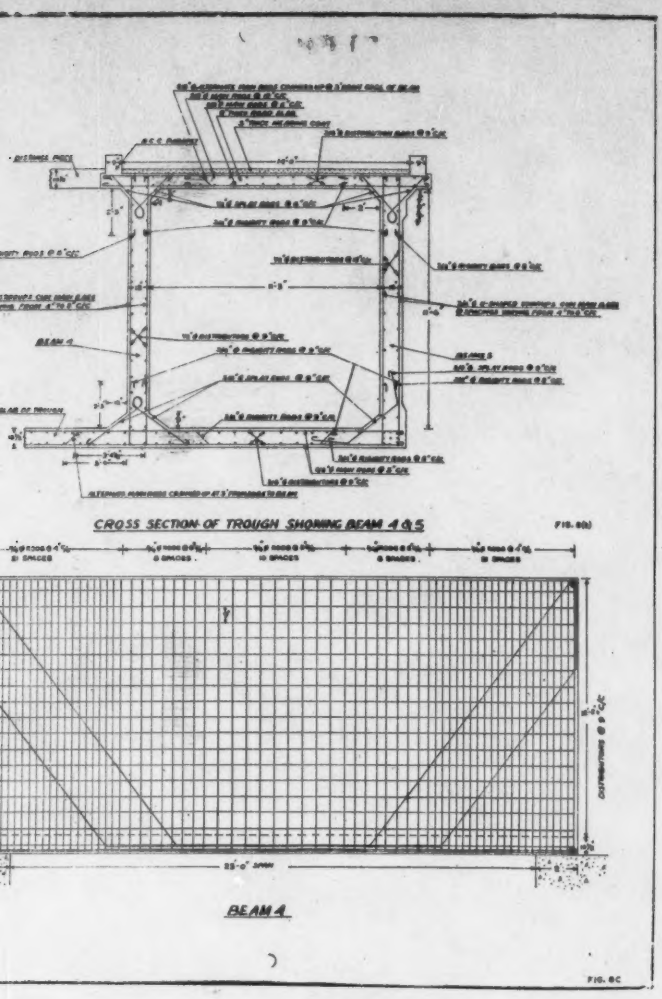
SECTION ON K-L

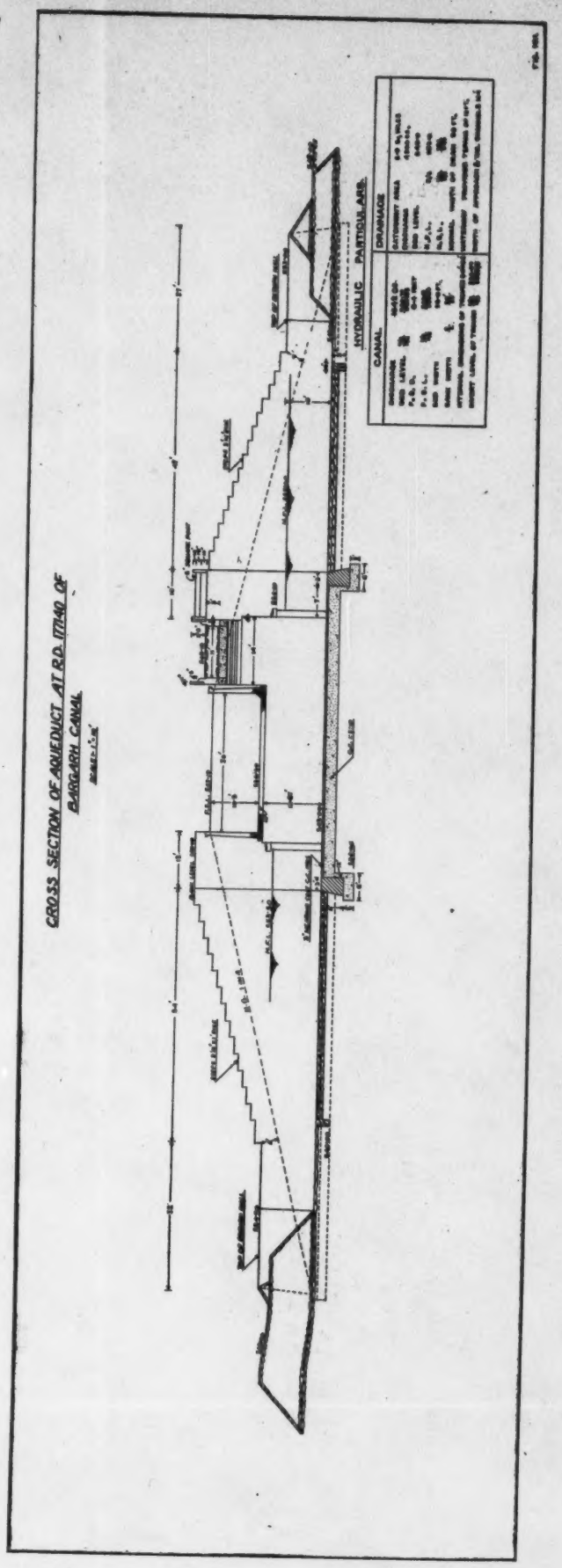


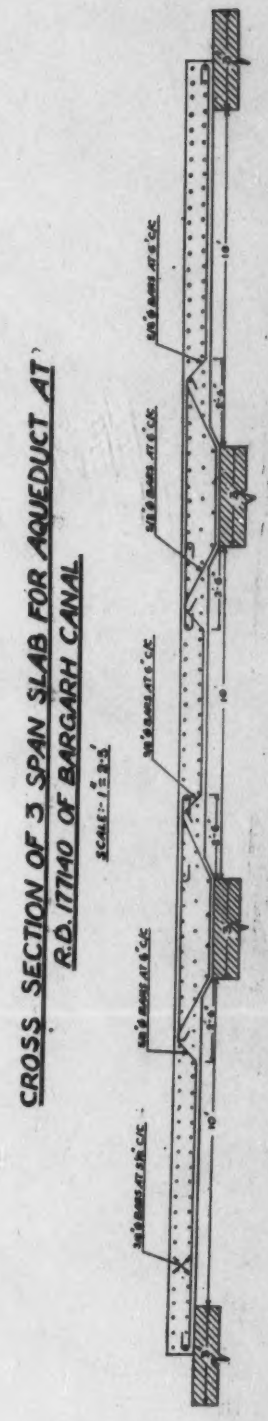
PLAN OF CURB

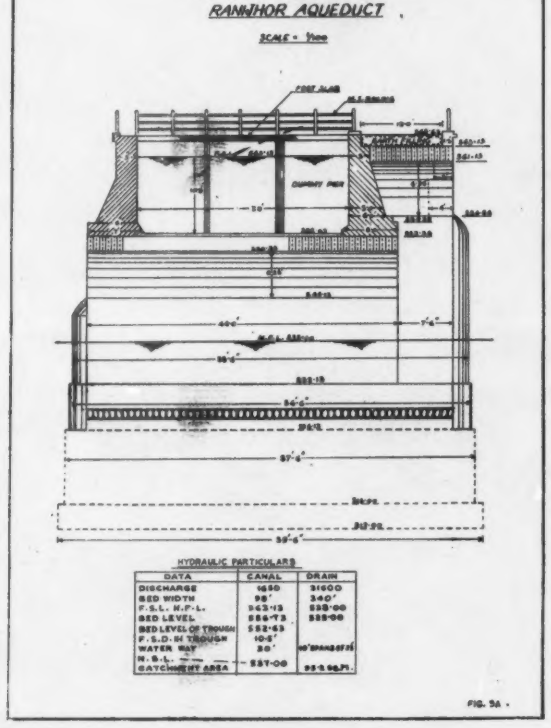
L-SECTION

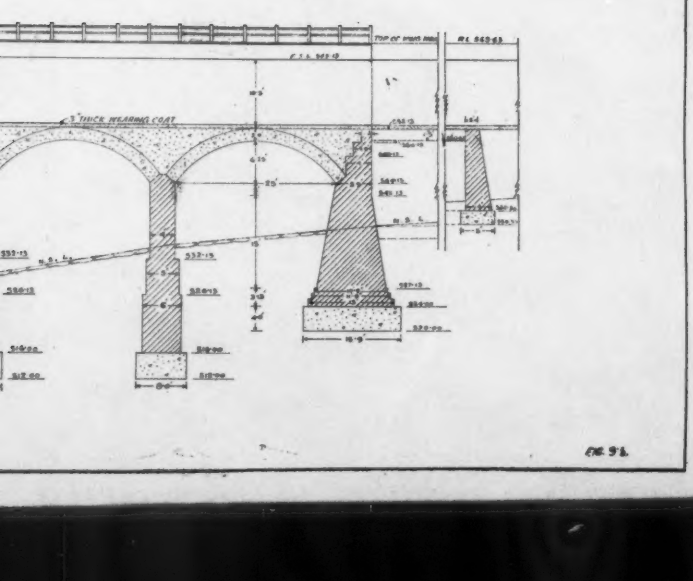




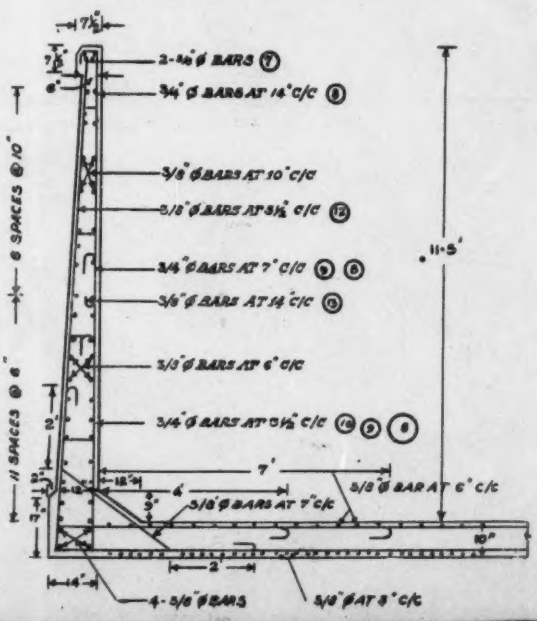





X-SECTION ALONG PIER OF RANJHOR AQUEDUCT
HYDRAULIC PARTICULARS
DATA | CANAL | DRAIN
DISCHARGE | 1650 | 31000
BED WIDTH | 98' | 340'
F.S.L. H.F.L. | 563·13 | 538·00
BED LEVEL | 556·73 | 525·00
BED LEVEL OF TROUGH | 552·63
F.S.D. IN TROUGH | 10·5'
WATER WAY | 30'
N.S.L. | 557·00
CATCHMENT AREA



Section Through Vertical wall at Midspan
for Aqueduct at RD 177140


2-1¼" ø BARS (7)
¾" ø BARS AT 14" C/C (8)
⅜ ø BARS AT 10" C/C
⅜" ø BARS AT 5½" C/C (12)
¾" ø BARS AT 7" C/C (9) (8)
⅜" ø BARS AT 14" C/C (10)
⅜" ø BARS AT 6" C/C
¾" ø BARS AT 5½" C/C (10) (9) (8)
6 SPACES @ 10"
11 SPACES @ 6"
11·5'
7'
5/8" ø BAR AT 6" C/C
5/8" ø BARS AT 7" C/C
4-⅝" ø BARS
⅜" ø AT 8" C/C

drainage vents. Over the arches the roadway is metalled and has a precast R.C.C. parapet on either side, while on the approach banks angle iron railings are provided. Expansion joints with copper strips and bitumen are provided at supports other than continuous supports. At the continuous supports the slab is held down to the piers by means of 3/4″ holding down bolts 4′ long spaced at 3′ centres. Between the drainage wing and the canal wing a slip joint of copper plate is provided to prevent cracks due to differential settlement.

Lining is done in the approaches as in the major aqueducts. The abutments, drainage wings and canal wings are designed in the same way as explained elsewhere.

Minor Aqueducts

Some of the distributaries are carried over relatively big drainages, by means of 18′ to 25′ span aqueducts with R.C.C. trough. The trough design is similar to that of the major aqueducts. Where inspection path is carried over the aqueduct, the trough is covered by a road slab. In other cases, suitable stiffeners are provided to keep the lateral rigidity of the trough. Another feature in such small aqueducts is that, in many cases, sufficient number of land spans necessary to accommodate the hydraulic gradient of 1:4 is provided in lieu of abutments, as the change is economical. (Fig. 11a). Where the canal discharge is small, say below 10 cusecs, the channel is carried through Hume pipes of diameter 1.5′ to 2′ on piers of masonry or same pipes filled with concrete (Fig. 11b).

Syphon Aqueducts

Syphon aqueducts have been provided in a few cases where sufficient head room is not available for the drain to pass freely under the canal. In such cases the drainage bed is lowered so that the drainage passes through an inverted syphon. Where water is carried in R.C.C. troughs they are designed on the same pattern as for the medium sized aqueducts with extra precuation to fix the bottom slab of the trough to the pier and abutment by holding down bolts, and provide reinforcement to resist the bending moment due to uplift under the trough. Some clear headway between the bed level of the drainage down-stream of the crossing and the underside of the culvert covering is provided. This is generally half the hight of the vent or 2 feet. (Figure 12).

Drainage Syphon and Under tunnels

Drainage syphons are essentially syphon aqueducts whose sides are earthen banks with complete earth slopes. They are provided where the width of the drain is small and the cost of bank connections are very high compared to the cost of the remainder of the work. Where there is sufficient head room available, an open culvert with free flow is adopted and it is called an under-tunnel. The drainage is taken through any one of the following types of culverts.

1. R.C.C. box.
2. Masonry barrel with covering of R.C.C. slab or masonry arch or half Armco pipe.
3. 6′ Armco pipe in single row or multiple rows.
4. 6′ half Armco pipe.
   (The Armco pipes are encased in reinforced concrete 1:3:5 12″ in thickness).
5. 1.5′ to 3½′ diameter Hume pipe.

The maximum velocity allowed through the first two types is 10′ per second while in the rest the maximum velocity has been limited to 8′ per second. The maximum flood discharge is found out and the type and size of barrel are fixed. Usually for a discharge of 200 cusecs and above masonry barrels are adopted. For discharge between 200 to 100 cusecs 6′ Armco pipes or half Armco pipes with side walls of masonry or mere half Armco pipes are used. For discharges below 90 cusecs Hume pipes have been adopted.

The invert level of the culvert under the canal is fixed such that the top of the covering is below canal bed and at the same time a clear headway of half the depth of the culvert is left between the underside of the roof and the downstream drainage bed. Where there is difficulty to get sufficient head room, the drainage bed downstream has been lowered suitably and a tail channel cut upto the place where its bed meets ground level. The drop at the upstream end of the culvert is generally over a drop wall but the lift at the tail end is always kept on a slope to facilitate clearing out silt and debris. The slope adopted is 1:5 in the D/S side and 1:3 in the U/S side. When the barrel is designed to flow full but the D/S H.F.L. is lower than the underside of the roof an R.C.C. hump of suitable height is provided at a distance of 4 ft. from the D/S end of the barrel so that the barrel may flow full. The lift wall is kept in the same level as the D/S drain bed level. The length of the lift wall has been kept generally at $1{\cdot}5/\sqrt{Q}$ and the depth of water over it calculated from the formula $Q = Cd \times B \times D^{3/2}$ where Cd is taken as 2.08 upto 100 cusecs, 2.30 upto 500 cusecs and 2.70 above 500 cusecs. The drop wall is of the same width as the lift wall. Top width of both lift and drop walls has been kept as 2′. The thickness at the bottom in the case of the drop wall is kept as 0.5H. The lift and drop walls are founded well below scour depth given by the formula $D = 1.25 \times \{0.9 \times (q^2/f)^{1/3}\}$
∴f is generally taken as 1.0.

The losses that are taken into account are the losses in entry and exit and losses due to friction. The frictional loss is calculated from Manning's formula $h_f = \frac{V^2 N^2 L}{1{\cdot}486^2 \times R^{4/3}}$. N is taken as 0.25 for Armco pipes, 0.15 for plastered surface of masonry barrels, and 0.16 for Hume pipes. The losses in entry and exit are taken as $1.5\ V^2/2g$ in case of pipes and $0.5\ V^2/2g$ or $0.8\ V^2/2g$ in the case of barrels depending on the splay of the wings. The total loss of head added to the D/S H.F.L. gives H.F.L. U/S of barrel. The H.F.L. upstream of the structure is derived by adding the afflux created above the drop wall which is obtained from the formula $Q = 3.09 \times A^{3/2} + 6.4 \times H \times A^{1/2}$ where Q = discharge per foot run on the drop wall, A, the afflux, H the height of the H.F.L. U/S of barrel above drop wall.

The structures are founded on mass concrete 3′ thick including 3″ wearing coat, in the case of canals and branches. For structures on the smaller channels if banks are low, foundation is of cement concrete 2′ in thickness. The aprons are designed for uplift pressure which can be calculated by drawing plan showing the canal banks, wings etc.

Where R.C.C. slab is provided as covering, it is designed separately for the channel section and bank portion and different thickness provided where necessary. Expansion joints of copper plates and bitumen are provided if the length is more than 50.′

In cases where there is likely to be uplift pressure on the covering of the barrel, R.C.C. slabs under the channel section have been designed to take the uplift pressure as well. They are well anchored to the piers and abutments by means of 4′ long 3/4″ dia. holding down bolts at 3′ centres. The half Armco pipes are also securely anchored to the foundation concrete or to the side walls where provided, for resisting uplift. The thickness of piers are kept as 1/3 to 1/5 span depending on the size of the structure subject to a minimum of 2′. The piers are extended and finished in a slope at the lift and drop walls, to resist uplift by self-weight and inducing arch action between piers. The top width of abutments are kept same as for piers. The top width of wings has been kept at 2′ in case of bigger structures and 1.5′. for smaller ones. The bottom width of abutments and wings are calculatd from the empirical formula of B=0.4H or 0.35H depending on the batter given to the walls. Generally a face batter of 1 in 6 is given for abutments, wings and returns. The wings are provided to retain the earth slopes with ample cover over hydraulic gradient. They are splayed suitably and the returns kept 1′ above H.F.L., are taken well into natural ground. Beyond the apron, some dry stone pitching is provided in bed, and revetments extend round the returns and beyond. (Fig.13)

Superpassages and Canal Syphons

Where the drainage bed level is sufficiently high above the F.S.L. of the canal the drain is carried over the canal in a superpassage. The design of the superpassage is similar to that of an aqueduct. No lining is provided in the drainage approaches. Ordinary dry stone pitching is done for some distance above and below.

The free board in the trough is increased from 1′ to 2′ as the vagaries of flood in a torrent is unpredictable. If the depth of flow in the trough is small, the superpassage can be used as a village road bridge for which the slab is generally safe. Where the drainage to be crossed is relatively quite big, say 100 cusecs or so and the channel discharge is only 25 cusecs or less, the channel is syphoned under the drainage through pipes with inlet and outlet wells. A self cleansing velocity of 2.5′ or 3′ has been allowed. The loss of head in the canal in this case willl be some-what high. The losses are limited to 0.25′ which gets adjusted in the nearest fall downstream. (Figure 14).

No level crossings have been provided in the Hirakud Canal system.

Road Crossings

Where the canal crosses an existing highway or a District road, bridges and culverts have been provided conforming to the requisite standards laid down by the I.R.C. In the case of village roads important road crossings have been bridged. In other cases, road bridges and foot-bridges are so provided at suitable intervals that easy access to all the villages served by the Canal is possible. In certain cases the road is diverted along the service road of the channel for a short length.

Wherever possible, road bridges and foot-bridges have been combined with the other canal structures like falls, regulators, escapes, aqueducts etc. as already mentioned while dealing with these structures. In other cases, they are different from the ordinary bridges over rivers and streams in the fact that, flow to be passed, section of the stream, velocity and levels of water are all controlled and defined. There will be no navigation and so the spans have been fixed purely on economical considerations. In a number of cases land-spans have been used to avoid high and costly abutments. In general, U shaped abutments with revetments on the sides have been adopted. The foundation of piers and abutments have been generally kept within 4′ to 6′ below bed level. Where possible stepped foundations have been adopted for returns and wings. In the case of National and State Highway crossings, whatever angle the existing road makes with the canal the same is kept in the design. In the case of small village roads the crossing is kept square.

Where the canal is in deep cutting arch bridges have been adopted. At other places R.C. Bridges of the T-Beam type or plain slab type have been adopted. Where the channels are small, pipe culverts have been provided. In a few cases where the F.S.L. of the channels is above the road surface, road syphons have also been provided. In such cases, in order to keep the syphon silt free an increased velocity of 3′ or so is allowed. An inlet well is provided for facilitating clearance of silt debris etc. In the case of very small channels where the full supply depth is 1.5′ and below, paved ramps of gradient 1:6 have been provided for wheeled and foot traffic. By the side of all the bridges, steps leading up to the canal are provided for the use of the public.

General

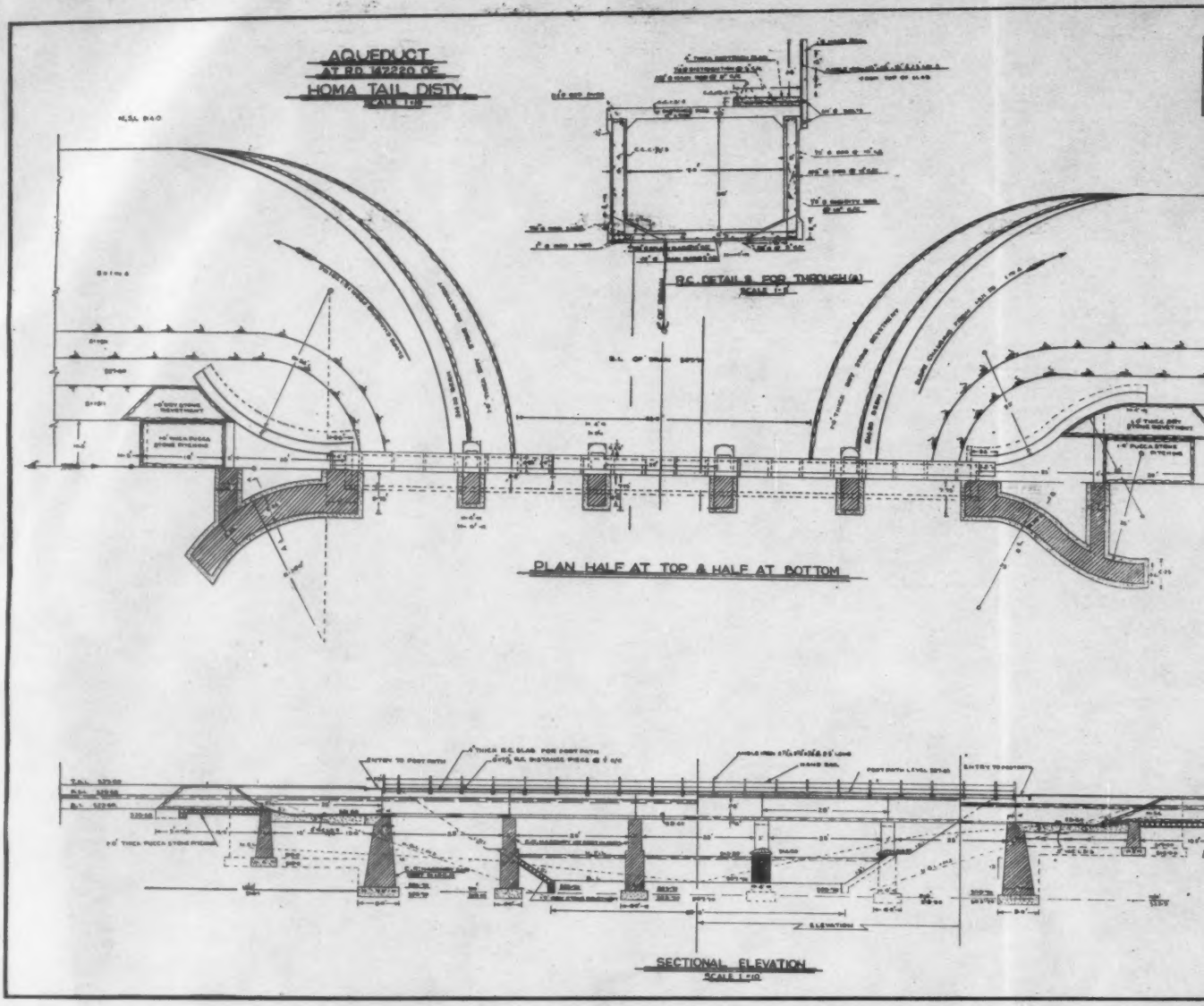
The designs have been made to satisfy fully the conditions at site which the designers have had full knowledge of. The emphasis has always been on practice rather than theory, though theory has been kept constantly in view. Designs and execution are being carried out side by side without detriment to progress, but with the great advantage of producing fuller and more appropriate designs. The number of structures in the Hirakud Canals is shown below.

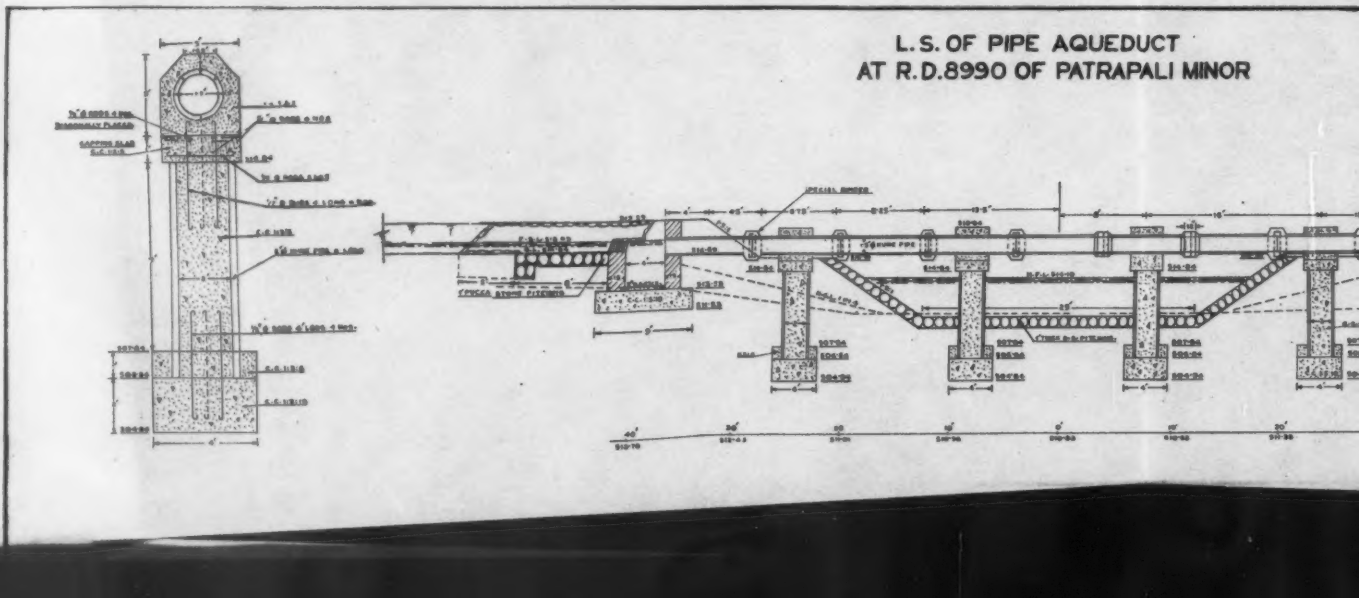
The designs of all the structures on the main canal and branches have been completed. In the distributaries and minors more than 800 structures have been designed. Over and above this individual designs for over 500 outlet sluices have been prepared.

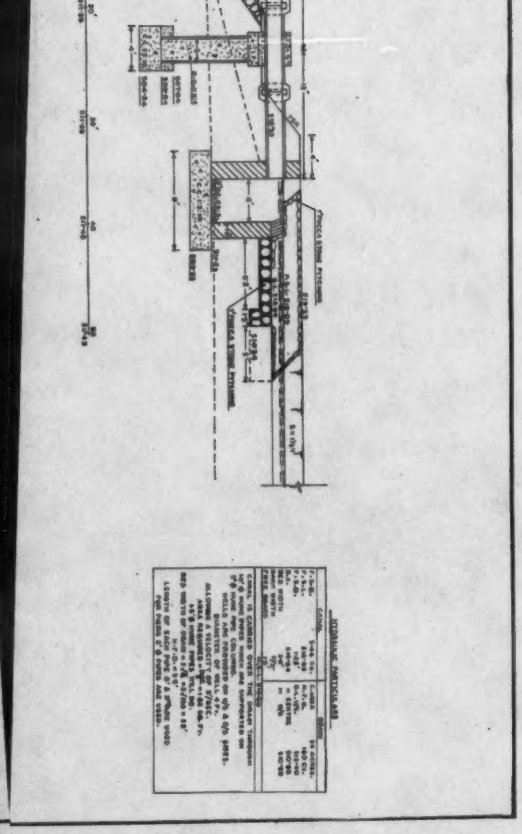
Details of masonry structures in the Hirakud. Canal System

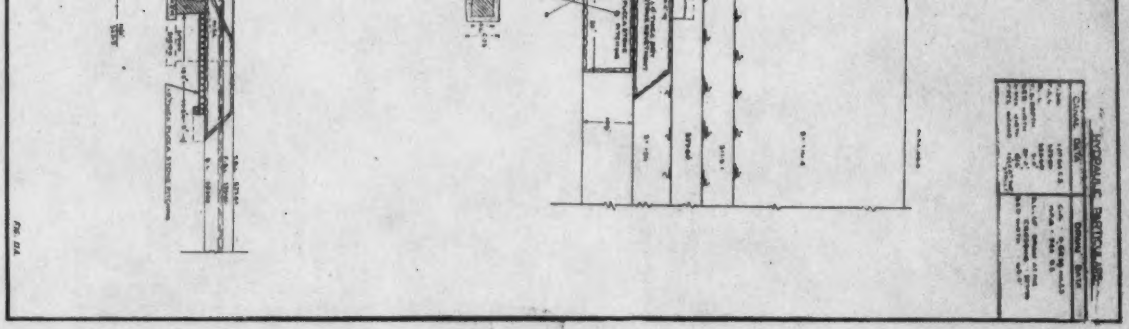
Sl. No.	*Name of the structure.*	*No. of structures.*
	Main Canals and Branches.	
1.	Regulators	60
2.	Falls	7
3.	Aqueducts	25
4.	Syphons	78

[*Continued on page* 120


AQUEDUCT
AT RD. 142220 OF
HOMA TAIL DISTY.
R.C. DETAIL B FOR THROUGH (A)
PLAN HALF AT TOP & HALF AT BOTTOM
SECTIONAL ELEVATION


L. S. OF PIPE AQUEDUCT
AT R.D.8990 OF PATRAPALI MINOR





CANAL SYPHON
A.D. 188500 OF
OMA TAIL DISTY
SCALE = 1" = 5'

HYDRAULIC PARTICULARS

CANAL.		DRAIN.
F.S.D.	10.62 Cs.	CATCHMENT AREA. 77 ACRES.
F.S.L.	503.74	H.F. DISCHARGE. (I=AREA IN SQ. MILES)
B.L.	501.99	X AREA IN ACRES.
F.S.D.	1.75'	= [320-77/640]·77 = 222 Cs
BANK WIDTH.	4'-6"	B.L. U/S. 500.70
BED WIDTH	2'-0"	" CENTRE. 500.50
N.S.L.	500.52	" D/S. 500.00

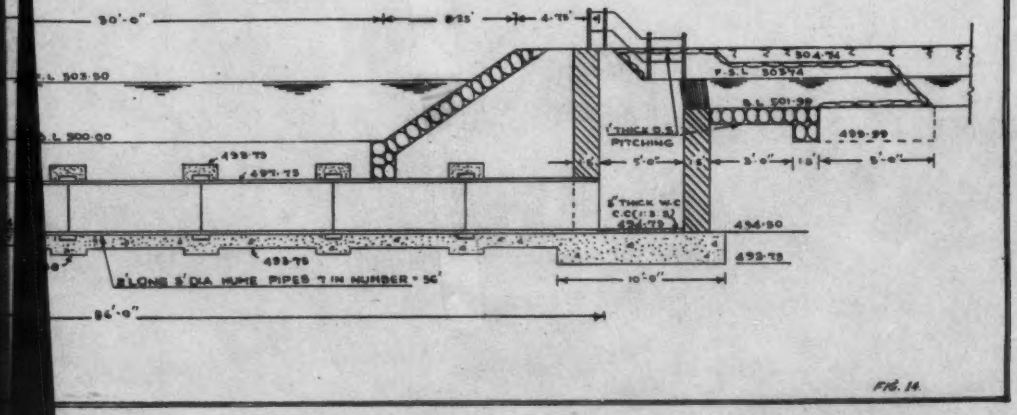
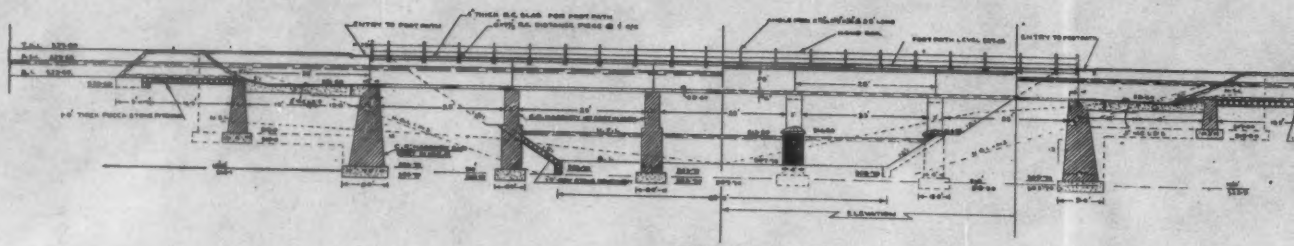


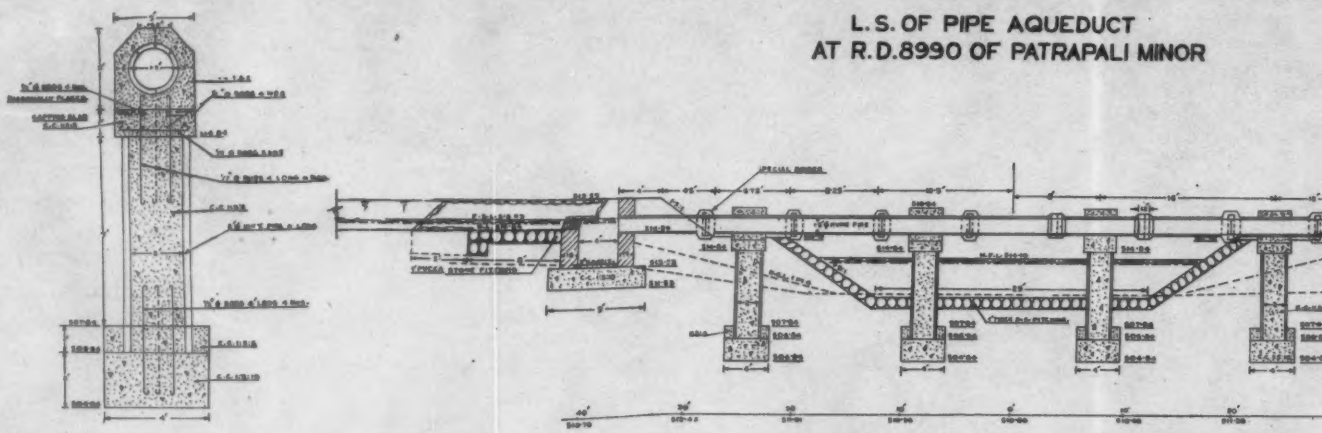
FIG. 14.

PLAN HALF AT TOP & HALF AT BOTTOM



SECTIONAL ELEVATION
SCALE 1"=10'

L.S. OF PIPE AQUEDUCT AT R.D.8990 OF PATRAPALI MINOR

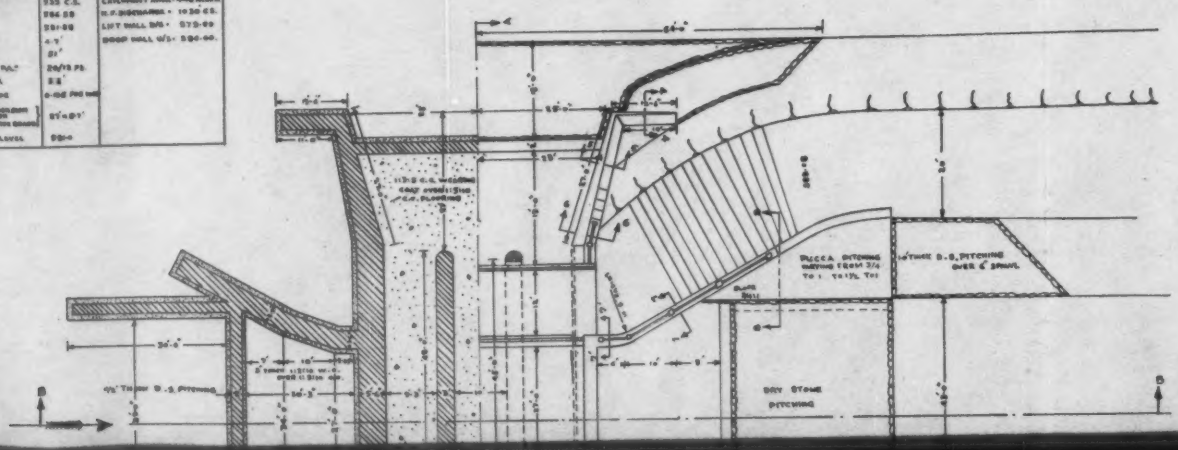


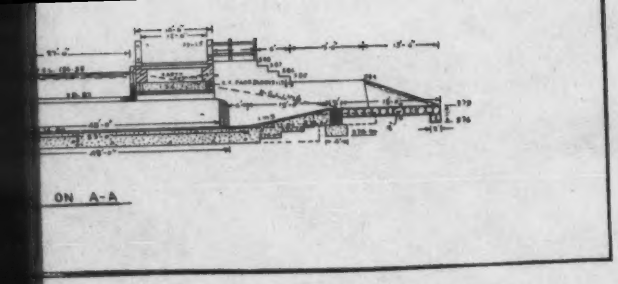
SYPHON - AQUEDUCT AT R.D. 84880 OF SASON CANAL

Scale :- 1"=8'0"

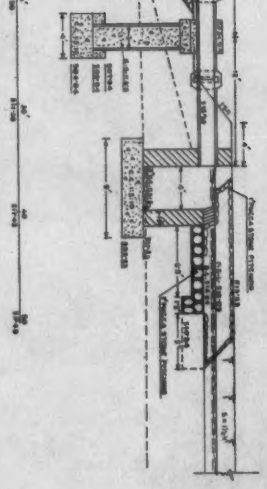
HYDRAULIC PARTICULARS

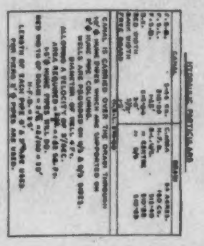
DESCRIPTION	CANAL	DRAINAGE
DISCHARGE	935 C.S.	CATCHMENT AREA- 648 ACRES.
F.S.L.	286.00	H.F.DISCHARGE = 1030 CS.
B.L.	281.00	LIFT WALL D/S = 279.00
R.B.DEPTH	4.5'	DROP WALL U/S = 280.00.
DEP DEPTH	20'	
[illegible]	26/13 Ft.	
TRUE GUAGE	22'	
WATER BLOCK	0.00 PRO MIL	
[illegible]	21'-0 21'	
SYPHONING LEVEL	286.0	

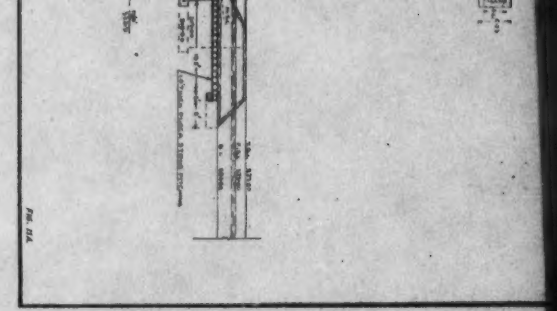




ON A-A







HYDRAULIC PARTICULARS

CANAL.		DRAIN.
F.S.D.	10·62 Cu.	CATCHMENT AREA. 77 ACRES.
F.S.L.	503.74	M.F.DISCHARGE. Q=AREA IN SQ.MILES
B.L.	501.99	x AREA IN ACRES.
F.S.D.	1.75'	= [3·77/640]·77 = 2·83 Cu.
BANK WIDTH.	4'0	B.L. U/S. 500·70
BED WIDTH	4'0	" CENTRE. 500·50
N.S.L.	500·25	" D/S. 500·40

CANAL SYPHON
AD. 188500 OF
OMA TAIL DISTY
SCALE - 1" = 5'

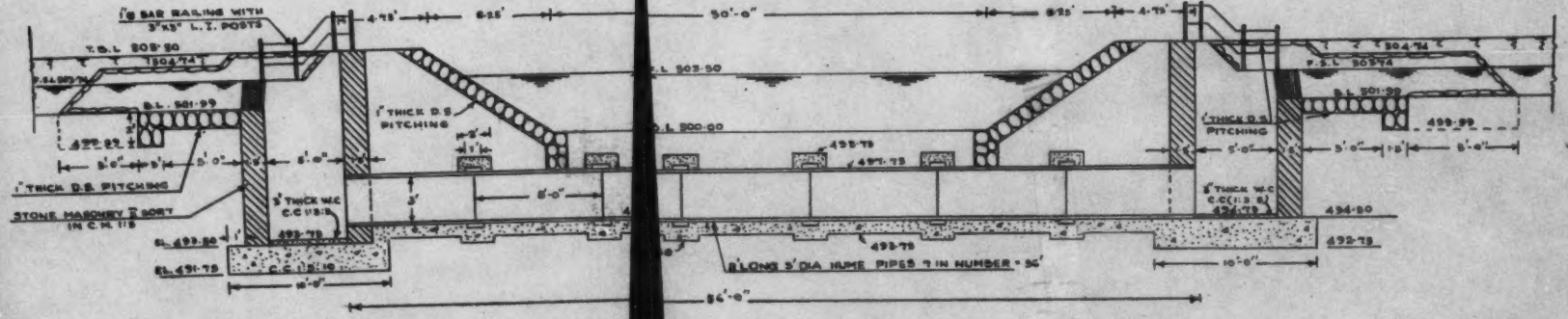
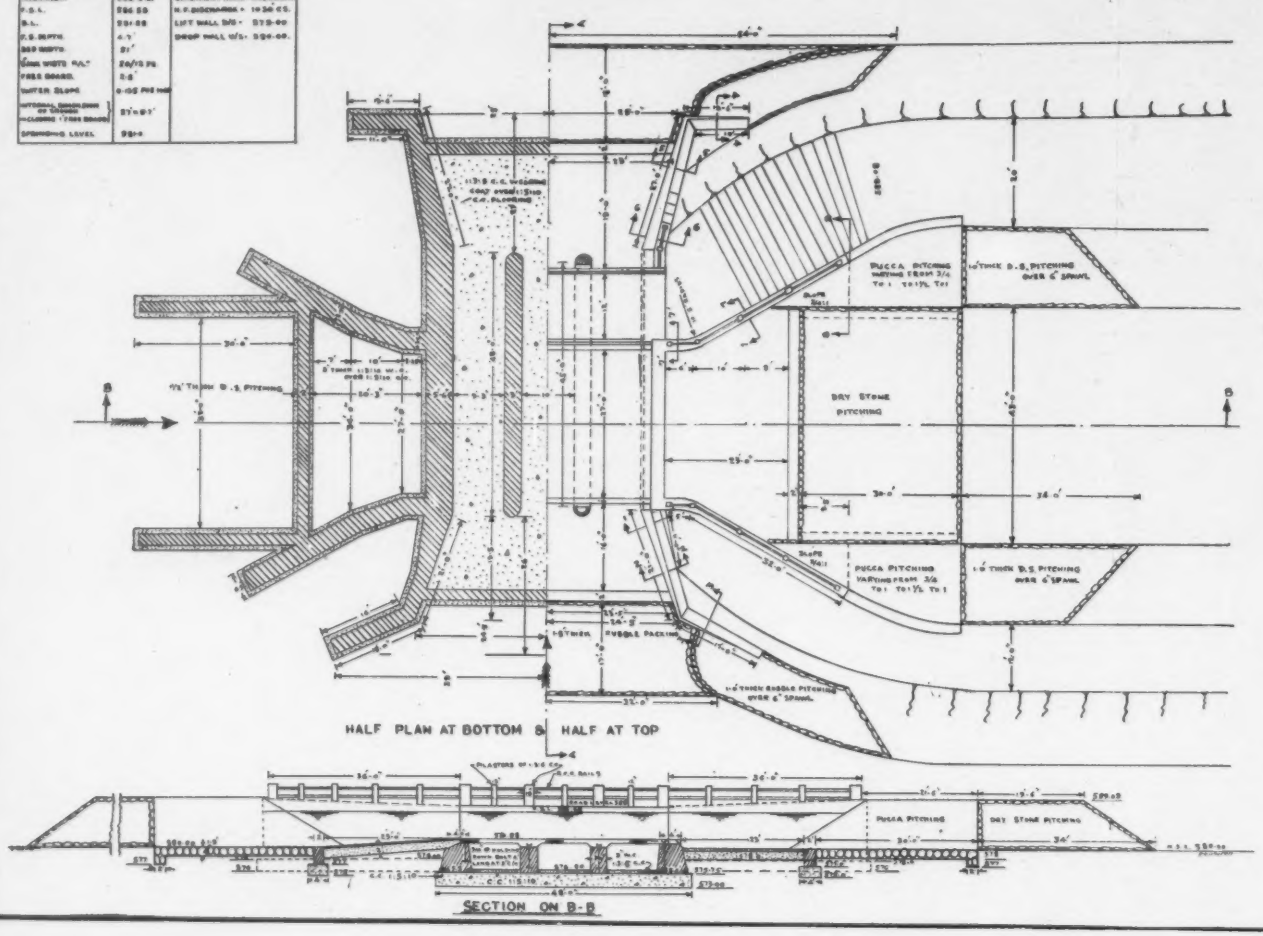


FIG. 14.

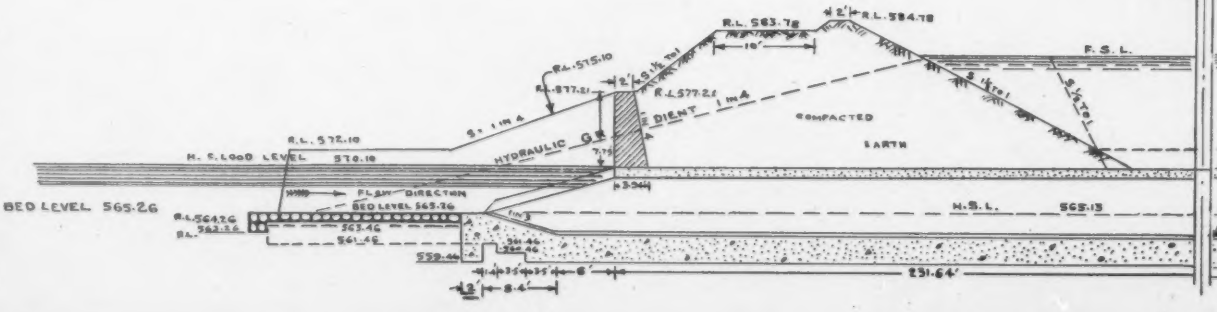
SYPHON - AQUEDUCT
AT R.D. 24860 of SASON CANAL
Scale 1" = 8 ft.

HYDRAULIC PARTICULARS

DESCRIPTION	CANAL	DRAINAGE
DISCHARGE	935 C.S.	CATCHMENT AREA - 648 ACRES
F.S.L.	586.58	H.F. DISCHARGE = 1936 C.S.
B.L.	581.88	LIFT WALL D/S - 579.00
F.S. DEPTH	4.7'	DROP WALL U/S - 574.00
BED WIDTH	21'	
SIDE SLOPE U/S	2½/1½ TO 1	
SIDE SLOPE D/S	1½ TO 1	
WATER SLOPE	0.102 PER 1000	
HYDRAULIC GRADIENT OR CHANGE OF LEVEL FROM BRIDGE	2'-0 1/2"	
SYPHONING LEVEL	581.0	


PUCCA PITCHING VARYING FROM 3/4 TO 1 TO 1½ TO 1
1'-0" THICK D.S. PITCHING OVER 6" SPAWL
DRY STONE PITCHING
PUCCA PITCHING VARYING FROM 3/4 TO 1 TO 1½ TO 1
1'-0" THICK D.S PITCHING OVER 6" SPAWL
1'-0" THICK RUBBLE PACKING
1'-0" THICK RUBBLE PITCHING OVER 6" SPAWL
HALF PLAN AT BOTTOM & HALF AT TOP
PUCCA PITCHING
DRY STONE PITCHING
SECTION ON B-B

DRAINAGE SYPH
BARGAR
SCALE



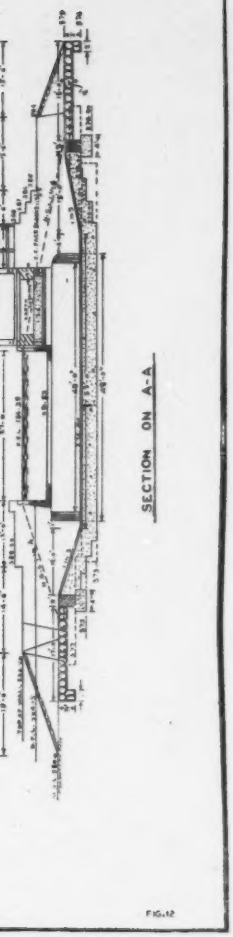


FIG. 12

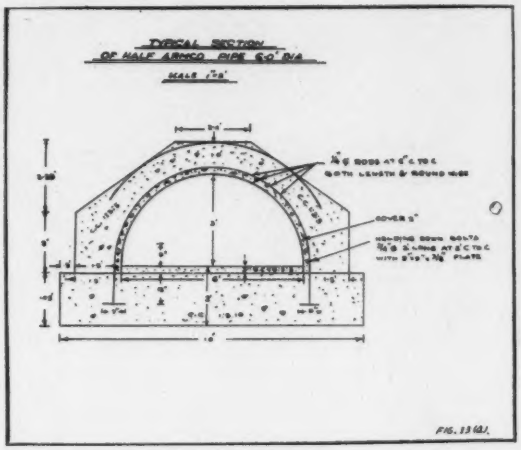
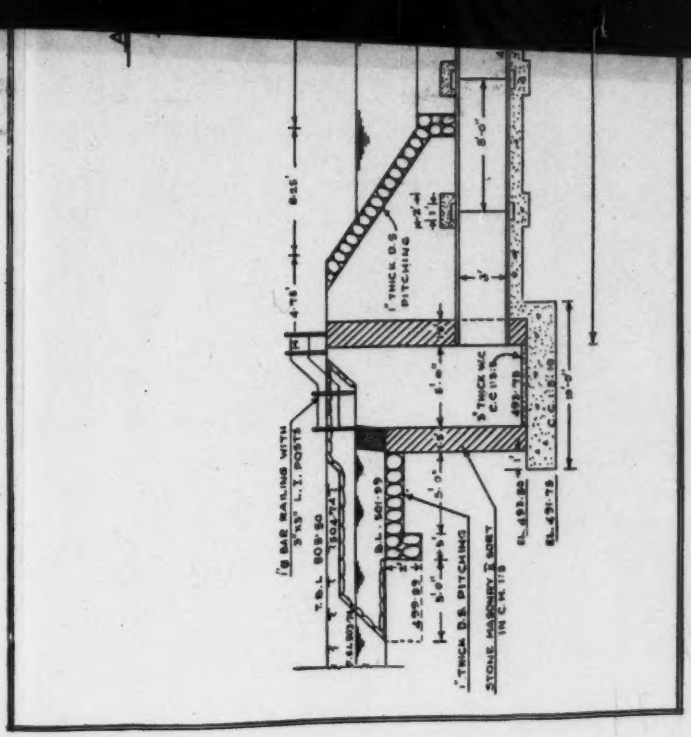


FIG. 13 (A)



SYPHON AT R.D 73520 OF
RGARH CANAL.

SCALE:- 1" = 10 FE.

HYDRAULIC PARTICULARS

CANAL	DRAINAGE
DISCHARGE. 2532 Cs	MAX. DISCHARGE 2109 Cs
BED WIDTH. 116'	WATERWAY 3 BARRELS 6'x6'
BED LEVEL. 572.00	
F.S.LEVEL. 581.28	VELOCITY 8.9'/SEC.
F.S.D. 9.2'	BED LEVEL 563.46 + 561.46

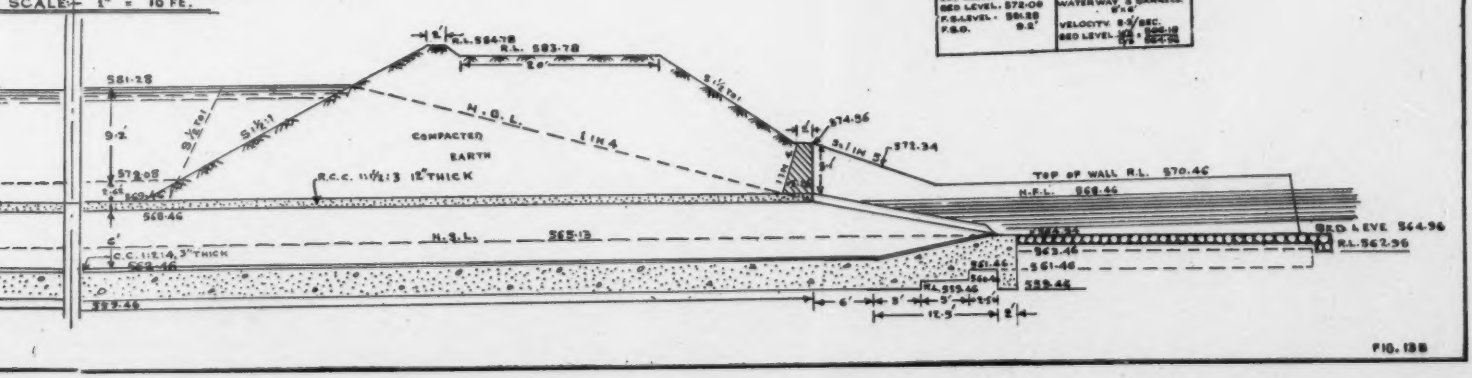


FIG. 13B

Economics of Hirakud

By

K. S. S. MURTHY, B.E., A.M.I.E. (India)
Executive Engineer, Hirakud Dam Project.

AND

B. G. PATTEGAR, B.E.
Assistant Engineer, Hirakud Dam Project.

The following contribution gives a broad idea of the economics of the expenses on and income from the Hirakud Dam Project. There has been changes in estimates and the causes of the same have been gone into. The various sources of income have been indicated and the attitude of the Orissa Legislature has also been referred to. All in all, it can easily be said that the Hirakud Project will transform the entire region from a backward one into one of the richest areas of India.

Orissa possesses immense water wealth in her five rivers (particularly the Mahanadi), large areas of cultivable land, big deposits of key minerals and a large population of intelligent and industrious people. By an integrated development of its natural resources and by harnessing of its man power, Orissa can become industrially, economically and politically great. The Mahanadi alone has an irrigation potential of over 20 million acres (if land to that extent is available) and a power potential of over 4 million k.W. which is nearly as big as that of Sweeden, and twice as big as that of Tennessee Valley. The great water way of the Mahanadi extending from the Central Provinces to the sea with a potential major deep-sea port at Chandbali or Dhamra will provide a most valuable artery of traffic.

Orissa's present position is analogous to that of the backward, agrarian Ukraine in the U.S.S.R. as it was before the completion of the Dneiper Dam in March, 1932. The construction of the Dneiper Dam transformed Ukraine into a prosperous agricultural and industrial area producing coal mining, metallurgical, power and electrical equipment ; steam locomotives, railway cars and automobiles, and aluminium, iron, high grade alloys, soda, nitrates, super-phosphates and other chemicals. The construction of the Hirakud Dam will similarly transform Sambalpur and Orissa into a prosperous agricultural and industrial area with unlimited possibilities for service to the Nation in peace and war.

The construction of the Hirakud Dam is therefore, of importance not only to the district of Sambalpur, Orissa and the neighbouring States, but also to India as a whole. It will give a most welcome lead to other parts of India, where, as in the case of Orissa, the water wealth of the region, which is now being wasted to the sea, can be harnessed in the service of the nation. It will mark the beginning of an era of higher standards of living for the common man, of freedom from floods, famines, want. drudgery, and disease.

Hirakud was conceived and approved as part of a plan for the unified development of Mahanadi Valley threatened with famine and floods.

The scheme was originally estimated to cost Rs. 47.81 crores and was sanctioned by the Government of Orissa in April, 1948. Subsequently on account of the general rise in prices, both in India and abroad, devaluation of the rupee, increase in labour wages and extension of the scope of the project, the original estimate was revised to Rs. 89.09 crores in 1951. A Committee of Experts was appointed by the Government of India in 1952 to examine these estimates and submit their recommendations. This Committee, known as the "Mozumdar Committee," revised the above figures from Rs. 89.09 crores to Rs. 92.08 crores on account of certain amendments and omissions and recommended to Government early sanction of the same so that work could be pushed with vigour. They also made suggestions and recommendations regarding the levy of betterment fee, water rates, distribution and sale of power, etc. The subsidiary dam and power house portion, which was a part of the Hirakud scheme, was abandoned in December, 1951 owing to the then need for higher priority for food production and limited financial resources. By that time the Hirakud Control Board was constituted and this Board, while considering the revised estimates, suggested certain further modifications like omission of delta irrigation, postponement of installation of additional units in the Main Power House, and omission of lift irrigation in Sambalpur.

The Board appointed a special committee with Member, Board of Revenue, Sambalpur as Chairman to go into the question of water rates and betterment levy and submit their recommendations. This Committee has made two reports—one for irrigation in Sambalpur District and another in the delta area. Based on this report, the Chief Engineer, Hirakud has worked out the financial forecasts for the Project.

The estimates thus revised stand at Rs. 70.78 crores consisting of.

	Rs. crores
1. Dam and appurtenent works ..	45.50
2. Canals	8.12
3. Power generation and transmission	16.27
4. Others	0.89
Total Rs	**70.78**

However, on the completion of detailed investigations, Government have approved in 1955 the execution of Delta irrigation scheme also estimated to cost Rs. 14.92 crores.

Subsequently due to the rapid growth of industry

and demand for power in this region the subsidiary power house scheme has also been approved in July, 1956. The addition of these two substantially improves the financial results of Stage I of the Project and this note explains in brief the financial forecasts from the combined proposals of Stage I, Delta, and Chiplima units of Hirakud Project.

Investments

	Rs. crores
Stage I (Irrigation in Sambalpur District and Main Power House)	,, 70.78 ,,
Delta Irrigation	,, 14.92 ,,
Subsidiary Power House at Chiplima	,, 14.32 ,,
Total	Rs. 100.02

Return

Hirakud is a multi-purpose project. Apart from irrigation and power, it will provide flood control, fish culture, recreation, navigation, etc. However, while assessing the financial returns, the return from fish-culture, etc., have not been taken into account. The returns will be from.

(*a*) Water rates from irrigation,
(*b*) Betterment levy on the land benefited by irrigation,
(*c*) Sale of power, and
(*d*) Flood relief tax in delta area.

Before an assessment of return from the Project as a whole is made it is a general practice to work out individually the returns from irrigation and power. In this case this is further sub-divided into return from Sambalpur irrigation, return from Delta irrigation, and return from a combination of the two systems. So also for power. Returns are worked out for power from Main Power House, power from Chiplima, and on a combined operation. For working out such returns the cost of common works such as dam and dykes should be allocated to the several constituent units.

Allocation of common costs

The Dam's objectives are flood control, hydropower, and irrigation water. The cost of the Main Dam and its appurtenant works should, therefore, be appropriately divided among these purposes. The 1947 estimate adopted a formula for this based on the capacities required for the three different purposes if the dam were built exclusively for each purpose. This is known as the "Alternative justifiable expenditure theory". The allocation on this basis was in the ratio of 37.83 : 20.56 : 41.61 among flood control, irrigation, and power. But the scope of the Project itself has since changed and that ratio is no longer applicable.

In the 1952 Revised Estimate the allocation was made on a different principle. The basis was the ultimate utility of the water for the various purposes. This eliminated the flood control purpose as a separate entity and merged it with the irrigation purposes on the score that the delta irrigation would be made possible only with flood control. Thus the costs were divided against irrigation and power in the ratio of 71 : 29.

The Mozumdar Committee (1952) which went into the revised estimates and the scheme as a whole, held rightly that no part of the flood control purpose costs should be charged to Sambalpur Irrigation as the latter was not affected by floods and that it was only the Delta Irrigation which derived the benefit. The Committee, therefore, adopted a ratio of 1 : 3 : 3 among Sambalpur Irrigation, Power, and Flood Control. In this initial ratio the Power quota of 3 was further divided into $\frac{1}{2} : \frac{1}{2}$ between power and delta irrigation, as the water after rotating the power wheels will go to feed the delta lands. Thus the ultimate ratio of division came to $5\frac{1}{2} : \frac{1}{2}$ between Irrigation and Power. Out of the $5\frac{1}{2}$ parts of the share for irrigation, the Sambalpur area should get 1 part while the other $4\frac{1}{2}$ parts would count against the delta area, if the flood control purpose were to be treated as entirely a Delta Irrigation benefit.

As, however, the actual method of working out the initial relationship is not properly established and as it is not proper to shift the emphasis from one to the other of any of three purposes for which this dam was first contemplated, it is now proposed to divide the cost of the dam among the irrigation in Sambalpur area, power generation and irrigation in delta area. The water required for power and irrigation has been calculated separately and works out to approximately 3.2 million acre feet for irrigation and 2.34 million acre feet for power. Therefore 3 million acre feet was assumed on an average as the storage requirement for either of the two purposes. The water requirements of Sambalpur area is about 1/4 of the total irrigation requirement. Allowing for greater seepage and transmission losses, being an upland steep-sloped country, it is more correct to take the water requirements of Sambalpur area as 1/3 of the total share of the irrigation requirements. Making an allocation of the cost of the dam in the first instance between Sambalpur Irrigation and Power on this basis the allocation would be 1 :3. But on further subdividing the power into cost for power and cost for delta irrigation on a fifty-fifty basis (the same water is utilised for both power generation and irrigation in delta), the final allocation of the cost of the dam and appurtenant works would be $1 : 1\frac{1}{2} : 1\frac{1}{2}$ for Sambalpur irrigation, power, and delta irrigation, respectively. It is also justified by the fact that the new area that will be benefited in the delta reach will be approximately $1\frac{1}{2}$ times the Sambalpur area.

Revenue from Irrigation

There are two types of revenue. One is a capital levy and the other a recurring one. The capital levy is known as 'betterment levy, and the recurring as 'water rate.'

Betterment levy:

Irrigation works constructed in India in recent years and those that are under construction are much more expensive than those constructed in the past, partly on account of the higher price level and partly on account of more difficult and, therefore, costly means of making the supplies available, like high dams, power for lifting water to high level, etc. For this reason and on account of the increased cost of maintenance and operation of these works, it will be difficult for many new projects to produce satisfactory financial results. The land owners benefited by these projects, apart from deriving increased annual profits, will in due course also get substantial increases in their land values. They will get these at

Statement 1

CUMULATIVE OUTLAY ON SAMBALPUR IRRIGATION (1 : 1½ :1½).

Year.	Outlay Unit I.	Outlay Unit II.	Total Outlay		Betterment Levy		Net Outlay
			Annual	Cumulative	Annual	Cumulative	
1948-49							
1949-50							
1950-51							
1951-52							
1952-53							
1953-54							
1954-55							
1955-56							
1956-57							
1957-58							
1958-59							
1959-60							
1960-61							
1961-62							
1962-63							
1963-64							
1964-65							
1965-66							
1966-67							

Statement 2

FINANCIAL RETURN FROM SAMBALPUR IRRIGATION (1 :1½ : 1½).

Year.	Net Outlay	S.I. at 3¾%		Net Revenue		S.I. Less net revenue Col. (3-5)	Net revenue less S.I.	Sum at Charge Col. 2+4—6	Percentage return 5/9×100
		Annual	Cumulative	Annual	Cumulative				
1956-57									
1957-58									
1958-59									
1959-60									
1960-61									
1961-62									
1962-63									
1963-64									
1964-65									
1965-66									
1966-67									

Statement 3

FINANCIAL RETURN FROM POWER (STAGE—I) (1 : 1½ : 1½).

Year.	Outlay on Civil Works in Lacs.	Outlay on P. Production in Lacs.	Outlay on T. Transmission in Lacs.	Total Capital outlay in Lacs.	Cumulative capital outlay in Lacs	Average capital outlay in Lacs.	Interest at 3.75 p.c. in Lacs.	Cumulative interest in Lacs.	Net revenue in Lacs.	Cumulative net revenue in Lacs.	Net revenue minus simple interest in Lacs.	Sum at charge 6+ 9-11 in Lacs.	Percentage return
1948-49													
1949-50													
1950-51													
1951-52													
1952-53													
1953-54													
1954-55													
1955-56													
1956-57													
1957-58													
1958-59													
1959-60													
1960-61													
1961-62													
1962-63													
1963-64													
1964-65													
1965-66													

the expense of the general tax-payer and in the fitness of things should bear at least a reasonable proportion of the cost of providing the benefits they reap. They should not be allowed to fully appropriate the unearned increment in the land values by the irrigation works executed through the efforts of the community at large. When the State provides some facilities for a section of the population, the beneficiaries should, according to the canon of sound financial principle, contribute, by rates and charges, sufficient revenue to cover both the capital and cost of maintenance of the necessary works. Another theory on which a capital levy is justified is to eliminate speculative profits. The levy should keep down land values within reasonable limit in irrigable areas. It is necessary for stability in rural area which is essential for full development.

The capital levy, in other words, is called betterment levy and it is to be paid by the beneficiaries of the projects. The levy represents Government share in the increased land values on account of execution of costly projects for the benefit of people in a particular area not through their individual effort but by co-operative activity of the community as a whole. The Planning Commission recommended that the States should take power to levy betterment charges in the new irrigation projects. It also recommended that the levy may be in the form of cash or lands from holdings above a prescribed size. By obtaining lands, the State will settle persons, whose lands are submerged by reservoirs or are acquired for other purposes connected with the project. Collection of land in this form will also help the Government in effecting improvements in agricultural economy by consolidation of holdings and by making assignments to landless people. The community purposes such as roads, markets, village forests, etc. might also be solved by this process. Betterment levy is to be imposed not over the whole culturable command but only on the area under irrigable command of the project.

Following this general directive, the Orissa Government has passed legislation regarding this levy. A section relating to the charges leviable reads as follows :—

"3. (*i*) The State Government shall be entitled to levy a betterment charge on every land under the irrigable command in accordance with the provisions of this act.

The lands under irrigable command shall be divided into suitable classes by the Government and the annual increase in the gross produce of each class of land shall be estimated :

Provided that all lands which according to the principle of classification adopted in settlement, are of the same class and which judged by their commandability are so situated as to derive the same amount of benefit from the scheme shall be placed in the same class.

Provided further that the estimate shall be made with reference to the average of the prices prevailing during the three agricultural years immediately preceding the agricultural year in which water is first supplied for irrigation in a block under estimation.

(*ii*) Ten times the annual increase in the gross produce estimated under sub-section (1) shall be deemed to be the increase in the capital value of each class of lands ; and the betterment charges payable in respect of such class of lands shall be one-half of the difference between the said increase in the capital value and the cost estimated in the prescribed manner of making the lands fit for advantageous irrigation under the scheme ;

Provided that in the cost of lands which were originally under dry cultivation and which with a view to derive benefit from the scheme were brought under wet cultivation, a sum representing the difference between the cost of wet cultivation and the cost of dry cultivation as determined in the prescribed manner shall be deducted from the increase in gross produce for the purpose of calculating the increase in capital value of those lands."

The betterment levy will vary with the type of land and the cost of making it fit for irrigation. There are several classifications of land in this area. Based on these and data of cost for improvement a rough assessment has been made of the probable amount to be realised from the project by way of this levy.

Water rates:

In addition to the capital assessment referred to above, a recurring charge is levied on all lands benefitted by irrigation. This is termed as 'water rate'. This levy varies from season to season and crop to crop. It is compulsory on all kharif crops and optional for the rabi. Most of the lands proposed to be irrigated are already under paddy cultivation. The kharif cultivation is expected to be developed within the next five years. There is no dearth of agricultural labour in the commanded area. Generally individuals of comparatively small resources holding large extent of land hold up development of irrigation. There seems to be no such trouble here. The water rate for kharif is proposed to be compulsory. This would facilitate the immediate expansion of irrigation.

Rabi cultivation is new in this area and so it may take some time for cultivators to get accustomed for this. However it would be safe to assume that it would develop to the full extent (the Project report assumes only 50% of the culturable commanded area to be irrigated in rabi) within the next 10 years. The State Government are cosidering making necessary legislation for this purpose.

Flood relief taxes

In addition to water rates and betterment levy it is also proposed to levy a flood relief tax in the delta area on lands that get the full protection. The total area that gets this benefit is 3,50,000 acres made up of 3 zones—80,000, 90,000 and 1,80,000 acres respectively—that will get the benefit. The flood havoc is assumed to be in three distinct degrees and so the tax will vary with respect to relief for each class of land.

Revenue from power

Power from Hirakud will feed various industries and consumers. The most important amongst them are:—

1.	Aluminium Factory at Hirakud ..	55,000 k.W.
2.	Steel Factory at Rourkela ..	60,000 k.W.
3.	Cement Factory at Rajgangpur ..	5,000 k.W.
4.	Paper mills at Brajrajnagar ..	4,000 k.W.
5.	Collieries and Refractory Factory near Jharsuguda	2,500 k.W.
6.	Ferro-manganese Factory at Joda ..	16,000 k.W.
7.	Mining loads at Noamundi, Joda, Koira and Rairangpur ..	14,000 k.W.
8.	Load at Cuttack	10,000 k.W.
9.	Bargarh	3,000 k.W.
10.	Station load and other miscellaneous town loads	3,000 k.W.

Indirect benefits and revenue

Other indirect benefits from the Project will be a considerable increase in employment opportunity for the people in agricultural, industrial, scientific and other pursuits, with consequent increase in their purchasing power and consumption of manufactured goods. This will result in increased income to the State from income tax, excise and other sources. In addition, there will be large increase in the capital assets of the State in increased land values as a result of irrigation and in the latent mineral wealth brought to the surface for economic utilisation.

Financial statements and revenue returns

Statements 1 to 9 indicate the various proformae adopted to work out the financial returns from the Project. Figures have not been indicated as the Government of Orissa have not yet finalised their decision on water rates. But it may be confidently stated that the scheme as a whole will be productive and be a literal "HIRA-KUD"—"Diamond Mine" of Orissa.

(*Continued from page* 116)

Design of Canal Structures: Some features of the Major Aqueducts

5.	Under Tunnels	3	
6.	Superpassages	2	
7.	Bridges	31	
8.	V.R.B. cum head Regulators	2	
9.	Escapes	3	
10.	Flush Inlet	1	
	total	212	Nos.
11.	Outlets	144	Nos.

Distys. and Minors.

1.	Regulators	95
2.	Falls	447
3.	Aqueducts	28
4.	Syphons	285
5.	Under Tunnels	4
6.	Superpassages	4
7.	Bridges	123
	Total	986 Nos.
	Outlets	1,397 Nos.

Acknowledgement

I am very greatful to Sri M. S. Thirumale Iyengear, I.S.E., M.I.E. (India), Chief Engineer, Hirakud Dam Project for the opportunity he gave me to associate myself with the Designs Section of the Mahanadi Canal Circle. I must also express my thankfulness to Shri K. Padmanabha Pillai, Ex. Superintending Engineer for his expert advice and constant guidance in the preparation of the designs. To him really must go, the credit for most of the designs referred to in this article.

(*Continued from page* 123)

Statistical Organisation in Hirakud

tion, is entrusted with the task of writing articles and writeups in various journals (Government and Private), issuing regular press notes, bringing out brochures, pamphlets and bulletins.

As is well known, the people of the neighbouring areas reacted adversely at the idea of a dam across the sacred river. It is only through the incessant efforts of the present Project authorities that they now feel that this mighty Project heralds the future which will make Orissa a land of plenty and prosperity.

Conclusion

The Statistical Unit has not built any part of the Hirakud Dam, Dykes and Canals, nor has it erected the giant Power House and the high voltage transmission network. But the Unit has beyond doubt served definite purpose in the execution of all this. Hirakud Dam Project has given a right lead in the matter of utilising statistical personnel on multipurpose river valley projects. It is expected more will be done in this direction in future.

Acknowledgement

I am highly grateful to Sri M. S. Thirumale Iyengar, the Chief Engineer of the Project for giving me the opportunity of writing this article.

Statistical Organisation in Hirakud

By

H. DUTTA MAJUMDAR, M.A.

Statistician, Hirakud Dam Project

AUTHOR

The importance of maintenance of statistics in construction project of such magnitude as Hirakud can hardly be exaggerated. The following contribution explains how it helps the engineer in maintaining a proper check on the construction schedule and the targets. Statistics also helps in so many other ways that may not be immediately noticeable. We therefore hope that the contribution will be read with profit.

With the rapid advance of the science of statistics in recent decades, it is being increasingly applied in almost all fields of study. It is therefore only natural that statistics should play a vital role in the planning and execution of the country's Five Year Plans. As is well known, lack of proper statistics gave rise to comsiderable confusion and imperfect planning in the initial stages. Gradually, the wrong has been undone. We have now reached a stage when we may confortably claim to have at least tolerably adequate data needed for progressive planning.

Construction of multi-purpose river valley projects was given high priority in the First Five Year Plan in view of their immense usefulness in the matter of flood control, irrigation and generation of cheap hydro power. In this domain, as in others, statistics will necessarily occupy a place of importance both at the time of investigation and planning and during execution. Need of statistics at the time of investigation and planning is obvious and therefore needs no particular emphasis. That it can also serve useful purpose during the period of execution of major river valley projects, is well revealed by the work done by the Statistical Units at Hirakud and the Damodar Valley Corporation. Leaving aside the D.V.C. Unit, it is proposed to give here a brief outline of the work that is performed by the Statistical Unit functioning at Hirakud.

Prior to August, 1953 there was no proper statistical organisation in Hirakud Dam Project though the provision of a Statistical Unit has all along been there in the organisational set up of the Project. A full-fledged section headed by a Statistician and comprising Statistical Assistant and other office assistants was opened only after the present Chief Engineer, Sri M. S. Thirumale Iyengar, took charge of the Project in June, 1953. This great project had already attached to it, a railway, a network of workshops, concrete and soil research department, a geological section, a comprehensive medical organisation and a labour office. Besides, there is a separate organisation—the Hirakud Land Organisation to look after acquisition of land for the Project and resettlement of displaced persons. It is therefore in the fitness of things that it should have a statistical department to look after the statistical side of the great work.

The Statistical Unit here is not so big but is definitely effective in its performance. The Unit works directly under the Chief Engineer through his personal assistant.

The work of the Section may broadly be classified as under :

(1) Collection and compilation of various types of statistical data involved in the execution of the Project and writing of reports.

(2) Keeping a close watch over progress of works and maintenance and compilation of all output returns—daily, weekly, monthly, quarterly, half yearly, and annual and writing of periodical reports and notes based on them.

(3) Acting as an information and publicity department of the Project. In this respect it has to devote itself to writing of articles and notes and publishing them in various journals throughout the country as also in Government publications. It has also to publish brochures, pamphlets and bulletins and issue press notes.

Collection and compilation of various types of Statistical data

Of the various types of data collected and compiled in the Section, the following deserves particular mention :

(*i*) Data relating to progress of various works on the project. This is naturally the most important of all the data collected by the Unit as the Project is yet to be completed. It is therefore proposed to discuss elaborately this point in the next section.

(*ii*) Related to the data of progress is the statistics relating to the health and efficiency of various machinery, particularly the earthmoving machinery, employed on the Project. A huge fleet of earth digging, loading and moving equipment of large capacities has been working on the project. These machines, working day and night, have built the huge 24-million-cubic-yard Main Earth Dam. A peep into their working—the available working hours, the actual hours put in, sickness of various types, idle hours due to nonavailability of spare parts, the percentage of efficiency, ect.—is essential. Such a study, while bringing out a real picture of machines working here and attendant difficulties, will definitely help us act in a right manner

in future whenever machines will have to be employed on a large scale.

(*iii*) Next comes the statistics of employment—the day-to-day employment position, the composition of the staff and labour, conditions of work, various amenities provided to them, earnings of labour, the statistics of accidents, etc. The Project has about 2,000 employees including engineers, other technical hands, and ministerial staff in its regular strength. In addition, about 10,000 workers—skilled and unskilled—work departmentally during peak periods of construction.

Besides, there are 20,000 workers employed by contractors. To keep a record of such a huge army of workmen is no mean job.

In 1954, at the instance of the Planning Commission, an attempt was made to assess the labour potential of the Project. The object was to arrive at the approximate number of mandays that has to be put in to complete all works on the project. This, it was considered, would help in assessing manpower requirements in various projects. Two different methods were followed and more or less the same result was arrived at by following these two methods. It was found that about 6 crores of mandays would be required to complete all works of stage I. This meant an average daily employment of about 25,000 workers. It is worth mentioning here that the actual labour employment on the project also gives nearly the same average.

(*iv*) Next to be mentioned is the meteorological and hydrological data—the rainfall, temperature, humidity, discharge and gauge observations, etc. Importance of such data is obvious in a major river valley project. A meteorological station attached to the Research Division of the Project records and reports daily statistics of rainfall, temperature, humidity, weather conditions, etc., at the Project site. Besides such day-do-day reports are also received by wireless or telegram from other raingauge stations situated in the upper catchment of the Mahanadi. Study of these data help assess the meteorological condition of the area over a long period. Daily discharge and gauge observations made at selected sites on the Mahanadi are also maintained.

In addition, the Unit collects and compiles various types of miscellaneous data. A notable work that has been done by the Unit is the compilation of the Revised Data Book of the Project. This book is, so to say, the Project Encyclopedia containing useful information about the Project in all its aspects. The unit has also contributed its mite in the surveys conducted from time to time in the Project area. In this connection special mention may be made of

(1) The Pilot survey of the Project area,

(2) The Indirect Benefits Survey of the Project area conducted by Gokhale Institute of Poona at the instance of the State Government,

(3) The FAO Survey on working class consumption etc.,

Standard forms and returns for collection of data

For systematic collection of data, standard forms and returns are required. These forms and returns should be prepared keeping in view the specific purposes they are meant to serve and introduced from the very beginning of the execution of a Project. Executive Officers in-charge of various works should know from the very start the particular forms and returns in which they are to report periodically. Otherwise, even if reports are submitted, these are not systematic and do not serve much useful purpose The experience at Hirakud confirms this. In the beginning there were, so to say, no standard returns. So, the reporting system was also in a confused state. In due course and particularly after the formation of the Statistical Unit, a number of forms and returns for submission of daily, weekly, and monthly statistics of labour, accidents, out-put, working of machinery, etc., have been introduced. (For samples of forms introduced on this Project plans see Appendix).

These forms, though not all-perfect, provide some basis for a good reporting system. However, my feeling is these should be improved still further (without making them too elaborate) and new ones deviced for use in all the River Valley Projects in India. In addition to these standard forms, subsidiary forms may be introduced by individual projects to collect information on subjects of local importance. These forms will be used by the subordinate offices in each project for sbmitting periodical reports to the head office. These will, for their very purpose, differ in nature, scope and frequency of submission from the standardised progress proformae introduced in all the River Valley Projects in August, 1955.

We are to do all this because it is not enough if we have executed a great river valley project. We must make a scientific study of how things have been shaped. It has always been the practice to make financial scrutinies. It is high time we should conduct comprehensive statistical studies in these projects and provide each project with adequate statistical personnel.

Watching the progress of works

(*a*) *Laying out an optimum programme.*

Here is a job of great importance. Everybody is aware that for the timely execution of such big projects involving numerous hazards, keeping up of progress schedules is of paramount importance. In this respect the first thing is to lay out a realistic programme of work which should neither be over-optimistic nor too pessimistic. An over-optimistic programme will lead to grievous disappointments at the end of each season and will consequently upset all calculations. A pessimistic programme on the other hand, will mean otherwise avoidable procrastination. It is, therefore, essential to weigh all odds and welcome factors after reviewing past achievements as well as failures and lay out an optimum programme. For, it is important to note that defficiency in any sector will delay the flow of benefits from the project as a whole. To strike at an optimum programme, planning had better move upwards from the lowest field level. So, it is the practice on this project to collect initial data from the field officers before the commencement of each season—the data moving upwards step by step—being checked and reviewed at each level, reaching finally the Chief Engineer. The final pro-

APPENDIX

1. **Progress Report Forms**

(*a*) Daily	Form	A-1, A-2, A-3.
(*b*) Weekly	,,	B
(*c*) Monthly	,,	C
2. Statistics of labour employment		
(*a*) Weekly	,,	D
(*b*) Monthly	,,	E
3. Statistics of accidents		
(*a*) Monthly	,,	F
4. Meteorological Data		
(*a*) Daily	,,	G
(*b*) Weekly	,,	H
(*c*) Monthly	,,	I
5. Hydrological Data		
(*a*) Daily	,,	J
(*b*) Weekly	,,	K
6. Reports on concreting, masonry and earthwork by Research Station		
(*a*) Daily	,,	L
(*b*) Weekly	,,	M
7. Working of Machinery		
(*a*) Daily return	,,	N
(*b*) Monthly returns	,,	O-1 O-2 O-3.

Form A-1

DAILY PROGRESS REPORT DATED THE.....

Items of work (Concrete, R.R. Masonry, Earthwork, Riprap etc., etc.)	*Total Estimated quantity.*	*Programme for the w/season*	*Daily Progress*	*Daily average programmed.*	*Actual Progress to date in working season*	*Programmed quantity to date in the w/season*	*Ahead(+) or Behind (—) programme*	*% of work done in w/ season*	*Target balance to be done for working season*	*Remarks.*
1	2	3	4	5	6	7	8	9	10	11
	cft.	cft.	cft.	cft.	cft.	cft.	cft.		cft	

Form A-2

DAILY PROGRESS REPORT FOR.....
(*Date*)
.....Sub-Division

Name of work	*Daily progress*	*Upto Date progress*	*LABOUR*			
			Dept		*Cont*	
			Sk.	*Unsk.*	*Sk.*	*Unsk.*

Cement report for.....
(*Date*)

Sub-Divisional Officer

Form A-3

FOUNDATION TREATMENT SUB DIVISION

DAILY PROGRESS REPORT OF DRILLING AND GROUTING OPERATIONS OF HIGH PRESSURE GROUT HOLES DATED.....

Serial No.	Feature	Hole No.	Depth Drilled			Total Footage drilled	Hole No.	Depth	Footage Grouted	Total Footage grouted
			From	To	Total					

Sub-Divisional Officer.

Form B

WEEKLY PROGRESS REPORT FOR THE WEEK ENDING.....

Name of Division.....

Serial No.	Name of items.	Progress achieved		Remarks.
		During the week	Up-to-date	
1	2	3	4	5

Form C

MONTHLY PROGRESS REPORT FOR THE MONTH

Particulars of work.	*Estimated quantity.*	*Target date of completion*	*Total progress to end of the previous season*	*Programme for the w/season.*	*Programme for the month under report*	*Progress during the month under report.*	*% of progress during the month Actual Programme 7/6 × 100*	*Programme of the w/season end of the month under report*
1	2	3	4	5	6	7	8	9

Form D

WEEKLY LABOUR STATISTICS FORM

(Average per day) For the week ending on.....

Name of the State	*Departmental*		*Contractors*	
to which the labour belongs	Skilled	Unskilled	Skilled	Unskilled

Form F

STATEMENT SHOWING ACCIDENT TO END OF.....19....

Particulars of works	*Total accidents to end of previous month*		*Accidents during the month under report*		*Total accident to-date*	
	Total No of accidents	*No of persons involved*	*Total No of accidents*	*No of persons involved*	*Total No of accidents*	*No of persons involved*
1	2	3	4	5	6	7

Form H

WEEKLY METERIOLOGICAL DATA RECORDED AT THE HYDROMET OBSERVATORY, HIRAKUD FOR THE WEEK ENDING SATURDAY.....

Date	*Maximum temp.*	*Minimum temp*	*Rainfall in inches*			*General remarks*	*Date*
			During past 24 hours	*Since the beginning of the month*	*Since the beginning of the calendar year*		

Form J

GAUGE READINGS AND DISCHARGE OBSERVATIONS FOR RIVER MAHANADI

Date.....

Searial No.	*Discription of site*	*Zero of Gauge*	*Gauge Reading*			*Discharge*	*Maximum gauge readings ever recorded*	*Remarks*
			6 A.M.	*12 Noon*	*6 P.M.*			
1	2	3	4	5	6	7	8	9

S.D.O., Hydrology.

Form C

MONTHLY PROGRESS REPORT FOR THE MONTH OF.....

Total progress to end of the previous season	*Programme for the w/season.*	*Programme for the month under report*	*Progress during the month under report.*	*% of progress during the month Actual Programme 7/6 × 100*	*Programme during the w/season to end of the month under report*	*Progress during the season to end of month under report.*
4	5	6	7	8	9	10

Form D

LABOUR STATISTICS FORM **STATEMENT S**

(May) For the week ending on.....

Particulars of work.	*Departmental*		*Contractors*	
	Skilled	Unskilled	Skilled	Unskilled
1				

Form F

ACCIDENT TO END OF.....19....

... to end of month	*Accidents during the month under report*		*Total accident to-date*	
... of persons involved	*Total No of accidents*	*No of persons involved*	*Total No of accidents*	*No of persons involved*
3	4	5	6	7

Form H

...DED AT THE HYDROMET OBSERVATORY, HIRAKUD FOR THE ...NDING SATURDAY..... **METERIOLOGICA**

Rainfall in inches				*Temperature*	
... past 24 hours	*Since the beginning of the month*	*Since the beginning of the calendar year*	*General remarks*	*Date*	*Maximum* / *Minim*

Form J

...HARGE OBSERVATIONS FOR RIVER MAHANADI

Date.....

Gauge Reading			*Discharge*	*Maximum gauge readings ever recorded*	*Remarks*
... A.M.	*12 Noon*	*6 P.M.*			
4	5	6	7	8	9

S.D.O., Hydrology.

.....

ogress during season to end month under report.	% of progress during the season		Total progress upto date	% of work done 13/2×100	Whether progress is upto programme	Remarks.
	Actual	Programme 10/9×100	Actual	Programme 10/5×100				
10	11		12	13	14	15	16

Form E

TEMENT SHOWING LABOUR STATISTICS FOR THE MONTH OF.....

work.	Departmental			Contractors		
	Skilled	Unskilled.	Technicians.	Skilled.	Unskilled.	Technicians.
	2	3	4	5	6	7

Form G

DAILY WEATHER BULLETIN

Weather chart for the past 24 hours ending.....A.M.
to day the.....

1. Temperature — Maximum / Minimum
2. Rainfall — during past 24 hours / since beginning of the month / since beginning of the year
3. Wind Direction
4. Relative Humidity — Maximum / Minimum
5. General Remarks

Form I

IOLOGICAL OBSEVRVATIONS RECORDED IN HYDROMET OBSERVATORY, HIRAKUD FOR THE MONTH OF.....

rature	Rainfall in inches			Wind Direction	Relative Humidity		General Remarks
Minimum	Past 24 hours	Since	Since		Maximum	Minimum	

Form K

WEEKLY HYDROLOGICAL REPORT FOR THE WEEK ENDING.....

The River.....

Discharge site.....

Dates	Gauge	Discharge observations.

Form L

Hirakud Research Station

Daily Report on Concrete and Masonry work

Location : Date

Inspector Reporting : Shift

1. Brief particulars of placing site and Mix Data :

Placing site	Mix From	Mix Ratio

2. Remarks regarding materials :
   (*i*) Cement :
   (*ii*) Aggregate/Rubble
   (*iii*) Sand

Comments, Recommendations and Brief Particulars of work at Site and Discussion Relating thereto :

Inspector-in-charge

Remarks, if any, by the visiting members of the Research Station :

EXECUTIVE ENGINEER
Designs and Research Division

Copy for Chief Engineer,
Through : SDO and XEN,
(with remarks, if any, by those officers)

Form N

EARTH MOVING MAC

Daily Progress

Section.....*Sub-Division*.....*Divi*

Serial No.	*Name and type of the machine*			*Time analysis*				
				M. hours lost due to				
	Basic Machine	*Dumpers*	*Total No. of working machine hours*	*Repairs*	*Waiting for supplies*	*For engines to get heated up*	*Any other cause*	*% of machine hours worked actually to total*

When a machine is idle, the rasons why it is idle must also be given in the remarks columns. Any damage to any machine requiring repla
in the report and where a machine has been sent to the worshop for repairs the fact and the data on which it was sent must be repor

Form M

Hirakud Research Station

Weekly Report for the week ending.....

SOIL MECHANICS SECTION

Site of construction	*Source of material*	*Location of the fill*		*Range of percentage compaction*	*Analysis of field compaction data in terms of lab. data*			*Remarks*
		R.D.	R.L.		*Above 98%*	96-98%	*Bellow 96%*	

CONCRETE SECTION

(*a*) **Concrete mixes**

Mix Ratio	*Remarks regarding aggregate, batching etc.*	*Placing site*	*Workability of mixes*

(*b*) **Concrete Mixes—report on curing** (*Size of cylinder used.....*)

Date of placing	*Water content lb/cyd*	*Cement content lb/cyd*	*Mix*	*Max size inches*	*Type of mix*	*Strength lb/sq in*	*Placing site*

(*c*) **Mortar Mixes—report on curing** (*Size of Cylinder used.....*)

Date of placing	*Proportion by volume*	*W/C (by weight)*	*Strength lb/sq. in.*	*Placing site*

orm N

ING MACHINERY

Progress Report

.....*Division*.....*Name of work*.....

	Output						*Machines sick in the*		*Remarks*
ine ked	*Lead*	*Capacity*	*No. of trips*	*Output in cft.*	*Compaction factor*	*Net output*	*Workshop*	*Field*	

ring replacements of parts of stoppage of more than a day will be reported in the remarks column. All field machinery should find a place t be reported in the remarks column.

Form O-1

Earth Report for the Machinery

Progress Report for the months of.....

Section.....Sub-Division.....

Name of work .....

1. Working expenses during the month
   - (*a*) Labour .. Rs.
   - (*b*) Materials excluding spares .. Rs.
   - (*c*) Spares .. Rs.
2. Cost of repairs carried out
   - (*a*) In the field .. Rs.
   - (*b*) At the Workshop .. Rs.
3. Total working cost .. Rs.
4. Total out-put (Excavation and dumping) .....Cft
5. Working cost per 1000 Cft (excluding cost of tyres and depreciation) .. Rs.
6.
   - (*a*) Depreciation during the day .. Rs.
   - (*b*) Cost of tyres per day .. Rs.
7.
   - (*a*) Depreciation per 1000 Cft. .. Rs.
   - (*b*) Cost of tyres per 1000 Cft. .. Rs.
8.
   - (*a*) Cost per 1000 cft including depreciation .. Rs.
   - (*b*) Cost per 1000 cft. including cost of tyres and depreciation .. Rs.

WORKING EXPENSES

Labour			Materials			
Item	*Noi*	*Amount for month*	*Item*	*Quantity*	*Rate Rs*	*Cost Per mo*
1. Operators			1. H.S.D.Oil			
2. Helpers			2. Mobil Oil			
3. Cleaners and Mazdoors.			3. Grease Oil			
4. Linemen, electrician, riger, sarangis etc.			4. Gear Oil			
5. Running and Maintenance staff fitters, machines etc.			5. Petrol			
*6. General establishment (W.C.)			6. Lubricants			
7. Other labour if any			7. Reeling waste			
Total			*Total*			

This includes worksarkars, khalasis, Timekeepers, Work Superintendent and foreman etc.

Form O-2

Monthly Progress report of earthmoving machinery for the month

of .....

Section.....Sub-Division.....Division.....

An Abstract of Output, Working Expenses, Depreciation and Fuel consumed during the month.

1. Name of the work

2. Date of commencement of the work

3. Depreciation
   (*a*) during the month
   (*b*) Upto date

4. Working Expenses
   (*a*) During the month
   (*b*) Upto date

5. Quantity of work done (Cft)
   (*a*) during the month
   (*b*) Upto date

6. Rate of depreciation per % Cft.
   (*a*) during the month
   (*b*) Upto date

7. Rate of working expenses excluding depreciation per % Cft
   (*a*) during the month
   (*b*) Upto date

8. Rate of working expenses including depreciation per % Cft.
   (*a*) during the month
   (*b*) Upto date

9. Fuel consumed with quantity.
   (*a*) during the month
   (*b*) Upto date

10. Quantity of work done per unit of fuel consumed.
    (*a*) during the month
    (*b*) Upto date

11. Cost of Fuel per % Cft of work done.
    (*a*) durig the month
    (*b*) Upto date.

Cost Rs. Per month.

Form O-3

MONTHLY PROGRESS REPORT OF EARTH MOVING MACHINERY FOR THE MONTH OF.....

Section.....Sub-Division.....Division.....

CAPITAL COST

Name of the Machine	*Original cost (Purchase conveyance to site)*	*Additions and Improvements*	*Total Capital Cost*	*Heavy repairs and overhauls*	*Grand Total*

Form O.1

Daily Report for the Machinery

Progress Report for the month of.....

Section ..... Sub-Division .....

Name of work .....

1. Working expenses during the month
   (a) Labour .. Rs.
   (b) Materials excluding spares .. Rs.
   (c) Spares .. Rs.
2. Cost of repairs carried out
   (a) In the field Rs.
   (b) At the Workshop Rs.
3. Total working cost Rs.
4. Total out put (Numerators and denoprnt)
5. Working cost per Item (1) (excluding cost of tyres and depreciation) .. Rs.
6.
   (a) Depreciation during the day Rs.
   (b) Cost of tyres per day Rs.
7.
   (a) Depreciation per Item (2) .. Rs.
   (b) Cost of tyres per Item (2) .. Rs.
8.
   (a) Cost per Item of working (Exclusive of depreciation Rs.
   (b) Cost per Item (2) (Including depreciation and tyres) Rs.

WORKING EXPENSES

Item	Labour			Materials		
	No.	Hours for month	Rate	Monthly Rs.	Units for month	Cost Rs. Per month
1. Operators						
2. Helpers						
3. Cleaners and Washers.						
4. Lubricants, electrolytes, fuses, consumables.						
5. Running and Maintenance stores (Tyres, maintenance etc.						
*6. Current total (Indirect) (1) (2)						
7. Other labour if any						
Total						

*This includes workmanship, khalasis, Timekeepers, Work Supervision and Foremen etc.

gramme for the season is then decided upon by the Chief Engineer keeping in view the target date of completion. All executive officers are then informed of the respective shares of the burden. In all this, the Statistical Unit of the project acts as a sort of a Central Planning and Coordinating Unit. Then from this annual programme, monthly and daily output targets are worked out and arrangements are made to commence work in right earnest from the very beginning of the season.

Then comes the next phase of the job—whether the schedules are being strictly adhered to. For this, a very close watch over the day-to-day achievements on various sections of the project has to be kept. And this is done by the Statistical Unit of the Project meticulously. In doing this, the Unit acts, one might say, as the watchdog of the entire construction organisation. The executive officers in-charge of various sections sends daily production returns which are checked and compiled in the Section and is brought to the notice of the Chief Engineer. Particular notice is taken of any deficiency occurring anywhere. The executive officer in-charge of the work is at once asked to take suitable action to cover it up in parlance with the general programme. If the factors causing short output are of a temporary nature the difficulty is easily overcome. If they are more or less of a persistent type then special attention is called for. It is also seen whether necessary steps have been taken promptly by executive officers in charge and the deficiency of output made up. In this way the daily output is maintained and all works progress as per schedule.

There is an important feature of day-to-day checking which deserves particular mention here. While a close vigilence is maintained over the quantum of output the quality of the work done is never lost sight of. It is already mentioned elsewhere in this journal that the Research Station of the Project does the field testing and quality control of various works in order to ensure that works are going on as per specification. Here it is not intended to narrate how this is accomplished. Suffice it say that a report on the day's work by the Research Station personnel is sent through the executive officers in charge of particular works. This report indicates particulars of the types of materials used, concrete batched and its placing, defects to be corrected etc. Executive officers' remarks are also furnished in that. The Statistical Unit then scrutinises these reports and submits them to the Chief Engineer with comments if any. If any defects are noticed, immediate action is taken to rectify them.

This is a picture in short of how daily check is maintained over the quantity and quality of production in different sections. After a week, the whole week's progress is reviewed and report prepared. So also after each month, quarter, halfyear and year. At any time, if any lapses are noticed in any section, the executive officer or officers concerned are directed to take immediate steps. At the close of season, the year's progress is reviewed and in the light of the progress achieved and difficulties encountered, the programme for the next season is prepared in the manner already discussed earlier. At Hirakud, the actual working season starts from October each year and ends in June next. The months of July, August and September are the wet months and practically no field work is possible during that period. Sometimes rains start from the beginning of June or even earlier. This period of more or less three months is therefore called the "slack season," when only 25% to 35% of the peak labour strength is maintained to push through essential works and carry out maintenance and repairs of machinery. The "slack period" is thus not allowed to go in vain. Rather, this is the time when all the machines are completely overhauled to bring them in perfect condition for the next season's work. This is also the time when the year's review of progress is made and coming year's programme laid out.

Here is a table indicating the targets and achievements during the last 3 seasons :

	1953-54		1954-55		1955-56	
	Programme	Progress	Programme	Progress	Programme	Progress
	(*in lacs cft*)					
Main Dam						
Concreting and Masonry	113.86	134.92	86.99	122.50	31.61	33.27
Earthwork ..	940.00	1052.05	940.00	1196.85	954.00	958.88
Dykes						
Earthwork ..	527.19	539.80	372.06	350.07	252.30	262.06
Canals						
Earthwork ..	763.85	763.85	729.92	729.92	719.01	750.79

It is evident from the above table that the progress of works at Hirakud has in general been much ahead of schedule. This made it possible to complete Stage I of the Project substantially within the target date.

Information and Publicity

Publicity has become part and parcel of our social behaviour and this has come to stay. Ours is a Government of the people. So people in all corners of the country have the right to know how things are going on in various parts of the country. The executive authorities in charge of affairs have, in turn, the bounden duty to keep the people informed of the conduct of their affairs. The authorities of this Rs.100-crores project are paticularly alive to this.

The common people in our country, though inherently good natured, are generally superstitious and ignorant of things happening around them. This makes publicity all the more significant. The job is not only to inform the public of what is happening but to make them realise what all this is about and how they are going to benefit and to persuade them to offer their sincerest co-operation.

The authorities of the Project take great care in this matter so that the local people as also the people elsewhere may know all about Hirakud—the scheme, its scope and aims, its salient features, special features of construction, nature of the construction organisation, employment position, labour welfare measures adopted, difficulties involved in various spheres, progress made from time to time, problems tackled, benefits to be derived from the Project, necessity of the whole hearted co-operation from the public, etc.

And for this, the statistical department of the Project, by virtue of its being the centre of informa-

(*Continued on page* 120)

longevity

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IIX 48

Role of Contractors at Hirakud

By

K. S. S. MURTHY, B.E., A.M.I.E. (India)

Executive Engineer and Personal Assistant to
Chief Engineer, Hirakud Dam Project

The following contribution gives an idea of the status of the contractors at Hirakud. Although it is known generally that the Project is being executed departmentally, contractors have played a significant part in its construction, as was but natural. In fact it was the result of the pooling of the resources and experience of both the Government and the Contratctors that the Hirakud Dam and its other aspects were completed so quickly.

Since independence India has embarked on numerous schemes of development, big and small. River Valley Projects form a major part of this programme of development. Hirakud, estimated at Rs. 70.78 crores (for stage I) is one such that was taken up soon after independence and substantially completed by the end of the first Five Year Plan.

In countries like United States, United Kingdom, Canada and other industrially advanced nations these developments take place at a fast rate. This is possible there because they have large contracting firms who could go into action at short notice ; they have firms which have the resources in men and machinery. Once Gvernment decide to implement a scheme and specifications are drawn up these companies bid for the job and take up construction from excavation of foundation to the final dedication of the Dam and commissioning of Canals and Power Plant.

In an undeveloped country like India such firms are few and when Government embarks on a huge programme, the hands of these few firms get full and so Government has to look out for alternate methods of construction. Hirakud is no exception to this.

When this Project was sanctioned in 1948, Hirakud was a thick forest. There were hardly any means of communication, particularly to the Right Abutment. Only a district board road passed near the Dam site in the left. There was no bridge across Mahanadi either here or lower down. The labour in the locality were all unskilled. There were hardly any contractors who could take up works of any magnitude. The engineers too had to start from scratch and build up their organisation. A Project of this magnitude requires a big force of labour. It would have been a herculean task had the Government to muster the entire labour force.

There is one strange thing about Hirakud. The Construction Organisation is under Central Administration. But the Project on completion becomes the property of Orissa. By means of an arrangement mutually agreed upon the Central Government is executing the scheme for Orissa. So the rules followed and the regulations adopted are all as per Central Code.

When decision was taken to execute the scheme the Government of India had to decide about the modus operandi : whether the scheme should be let out on contract in *toto* or whether it should be executed "*Departmentally*". At that time there was no Indian construction firm capable of handling such a big scheme. Only foreign firms, mostly American, could bid for the scheme. It was, therefore, decided that work should be carried out on departmental basis. This enables Government to train a large number of Indian personnel in such construction and also it made it possible for them to utilise the large quantities of surplus disposal stores and equipment.

Initially the execution was in charge of the Central Waterways Irrigation and Navigation Commission. The rules were adopted as in Central Public Works Department. Later on a separate Accounting Handbook was prepared to be followed on this project. This was drafted mostly on the experience gained in Punjab and on adoption of certain Central rules and regulations.

With the tempo of work gradually building up contractors and labour from other parts of India started coming in. The partition and its aftermath helped Hirakud in finding a large group of workers mostly skilled technicians, engineers, overseers, draftsmen etc. The place began to hum with activity with people from different parts of the country. The people of Orissa and adjoining areas also found plenty of opportunity for employment and business. Instances are not lacking where past truck-drivers have now become flourishing contractors owning their own fleet of lorries.

What then is the role of contractors in Hirakud and what is the contract system ? These are certain questions that would crop up in any one's mind.

It is true in Hirakud we do not have any one contractor responsible for the entire construction. But it is also to be remembered that not all the works are carried out "Departmentally" i.e., by the force-account system—the department engaging its own labour and supervisory personnel. The department is doing the entire earthwork on main dam, the manufacture and transport of a major portion of concrete for Spillway and Power Dam ; excavation of Power Channel ; excavation of Bargarh Canal and branches in deep cut reaches and building embankments in approaches of large aqueducts. Rest of the work is

done through contractors. In certain cases, however, there is an intermingling of the two systems.

The contractors in Hirakud can be grouped as follows :

1. Civil works contractors.
2. Metal works contractors.
3. Contractors for supply of electrical plant and equipment and.
4. Those who supply stores and machinery.

The contractors for civil works are classified into 4 categories :

Class I Those who could be entrusted with works above Rs. 5 lakhs and upto any amount.
Class II Those who could be entrusted with works between Rs. 5 lakhs and Rs. 1 lakh.
Class III Those who could be entrusted with works between 1 lakh and Rs. 10,000.
Class IV Those who could be entrusted with works below Rs. 10,000.

Recently sanction of the Government has been obtained exempting from enlistment those contractors in canals and transmission lines who execute works costing less than Rs. 1,000.

In the early stage there was no classification of contractors nor any registration compulsory. It was found that some contractors took up works beyond their resources and capacity. This resulted in serious failure on their part resulting in upset in programme of works and at the same time in financial loss and inconvenience to those people. At present the system of registration is followed strictly. There are 15 class I contractors, 44 class II contractors, 114 class III contractors, and 377 class IV contractors. This excludes firms which supply stores and equipment. Statement I (see end of article) indicates the names of Class I contractors who are working or have worked on this Project. These contractors are individuals or partnership firms or limited companies. They hail from different parts of the country. It may be of interest to note that during the peak period of construction, labour employed by the contractors vis-a-vis that engaged directly by the department was as follows :

	Departmental		Contractors'	
	Skilled	*Unskilled*	*Skilled*	*Unskilled*
1954	3,344	5,041	2,273	17,061
1955	4,566	6,152	3,102	24,014
1956	7,768	9,037	2,986	23,703

This should give a rough indication of the extent of contractor's share in the building of Hirakud. Statement II (see end of article) indicates the civil works handled and the turn-over (approximate) in rupees of their transactions.

Metal Works Contractors

There are four major contractors under this category

1. M.A.N. West German firm through their agents in India, Escorts(Agents). Limited,
2. Jessop & Co. Ltd.
3. Textile Machinery Corporation Ltd.,
4. K.G.Khosla & Co.

The M.A.N have supplied the 64 deep sluices and their embedded parts, four sets of emergency gates and embedded parts, hoisting equipment etc. Total tonnage supplied by them is 4,157 tons, estimated to cost Rs. 81.05 lakhs. The company has also furnished under a supplemental agreement the services of erectors who, with the help of Indian skilled labour at site, have erected these gates and have trained them in their operation. The two 100 ton gantry cranes for operation of the bulk-head gates and emergency gates are also supplied by them.

Jessop & Co. Ltd. have supplied the 34 crest gates, 51′ × 20′ each, along with their hoist and other embedded parts. Their contract is worth Rs.24.51 lakhs for the supply and istallation of 1,527 tons of equipment.

A French company through their Indian agents. K.G.Khosla & Co. have supplied the Penstock head gates for Units 1 & 2. They have also furnished a supervising engineer for the erection.

Textile Machinery Corporation Ltd. have supplied the huge penstocks of 25′ diameter embedded in the power dam for units 1,2,5,6 &7. This contract is worth Rs. 18.35 lakhs for a tonnage of 448. Penstocks for unit 3 & 4 were supplied by the turbine manufacturers themselves.

The Tungabhadra Workshops have supplied the head gates for the Bargarh and Sason canals and Sambalpur distributory. Gates and other gate parts for the draft tube outlets of power house, shutters for the canal sluices and regulators have been manufactured in the the Hirakud Workshop itself.

Contractors for Electrical Plant

The Major firms who have supplied electrical plant and equipment are :

1. English Electric Company, Ltd.
2. Voith,
3. Siemens,
4. Assoeiated Electrical Industries(India) Ltd.
5. General Electric Company Ltd. of England.

These have also supplied on supplemental agreements the services of their erectors and supervising engineers for actual erection and supervision. Statement III furnishes in brief the cost of equipment supplied by these firms.

Other Contractors

There are a number of firms and individuals supplying plant and equipment, particularly earthmoving machinery. Mention may be made in this connection of the firms:

Blackwood Hodge (India) Private Ltd,
B.K.Khanna & Co. Ltd.
William Jacks & Co. Ltd.
Tractors (India) Limited.

Several other firms supply the Project various spares for machinery, different types of stores, tools and tackle etc.

Another important group of contractors whose contribution to the success of Hirakud is by no means

Statement III

COST OF ELECTRICAL EQUIPMENT SUPPLIED BY FIRMS.

		Rs.
M/s English Electric Co.	Turbines and Generators for Power House	1,27,43,400
M/s Protos Engineering Co.	Turbines and Generators for Power House.	1,48,21,200
M/s A.E.I.	Indoor and Outdoor Switch Gear and Transformers for Power House	69,44,000
M/s G.E.C.	Additional material for Grid Sub-Station.	2,94,800
M/s G.E.C.	Supply of Transformers and Switch gear for Grid Sub-Station.	86,51,700
M/s Protos Engineering Co.	—do—	26,46,300
M/s Protos Engineering Co.	—do— for Rourkela Sub-Station.	45,51,200
M/s B.I.C.C.	Transmission Line Materials.	1,34,07,200
M/s Kamani Engineering Co.	Insulators 132 KV and 66 KV.	2,81,900
M/s Nicco.	Earth Wire.	84,900
M/s Al. Industries Ltd.	Conductors for 132 KV Single Circuit	26,19,200
M/s S.A.E., Italy.	132 KV Double Circuit Towers.	15,40,000
		6,85,85,800
	Cost of Equipment obtained for Power House No. 2.	53,07,000
		7,38,92,800

Statement IV

LIST OF SUPPLIERS WHO HAVE SUPPLIED MACHINERY AND EQUIPMENT TO THE HIRAKUD DAM PROJECT

1. M/s William Jacks & Co. Ltd. 16, Netaji Subhas Road, Calcutta-1.
2. M/s Voltas Ltd., 8, Netaji Subhas Road, Calcutta-1.
3. M/s Marshall sons & Co. (I) Ltd. 33/1 Netaji Subhas Road, Calcutta.
4. M/s B. K. Khanna & Co., Connaught Circus, New Delhi.
5. M/s Martin Burn Ltd. 12, Mission Row, Calcutta.
6. M/s Bird & Co., Chartered Bank Buildings, Calcutta-1.
7. M/s E.M.Allcock & Mohatta, 19, British Indian Street, Calcutta-1.
8. M/s B. R. Herman & Mohatta, 19, British Indian Street, Calcutta.
9. M/s Vulcan Trading Co., 19, British Indian Street, Calcutta.
10. M/s Jost's Engineering, 19, British Indian Street, Calcutta.
11. M/s Consolidated Pneumatic Tool Co. Ltd., P.O. Box No. 805 Calcutta.
12. M/s Pashabhai Patel & Co., Construction House, Ballard Estate, Bombay.
13. M/s Tractors (I) Ltd., Post Box No. 323, Calcutta-24.
14. M/s Blackwood Hodge (I) Private Ltd., 139, Beliaghata Road, Calcutta-15.
15. M/s Dewars Garage & Engineering Works Ltd., 4, Council House Street, Calcutta-1.
16. M/s Mahindra & Mahindra Ltd., Gateway Buildings, Apollo Bunder, Bombay.
17. M/s Greaves Cotton & Co., 16, Hare Street, Calcutta.
18. M/s Associated Exports Imports Corpn., 8B, Lall Bazar Street, Calcutta.
19. M/s Bahri & Co., P-39, Mission Row, Calcutta.
20. M/s Ingersoll Rand (I) Ltd., 7, Wellesley Place, Calcutta.
21. M/s General Electric Co. (I) Ltd., Magnet House, Chittaranjan Avenue, Calcutta-13.
22. M/s Philips Electrical Co., Ltd., Philips House, 7, Justice Chandra Madhab Road, Calcutta-20.
23. M/s Associated Electrical Industries (I) Ltd., Crown House, 6, Mission Row, Calcutta.
24. M/s Greaves Cotton & Cromption Parkinson, 4, Mission Row, Calcutta-1.
25. M/s F & C. Osler, 12, Old Court House Street, Calcutta-1.
26. M/s British Insulated Callender's Cables, 9, Hare Street, Calcutta.
27. M/s Indian Cable Co. Ltd., 9, Hare Street, Calcutta.
28. M/s Parry & Company, Mercantile Buildings, Lall Bazar Street, Calcutta.
29. M/s Imperial Chemical Industries (I) Ltd., 34, Chowringhee, Calcutta-16.
30. M/s Indian Oxygen & Acetylene Co., Ltd., 48/1 Diamond Harbour Road, Calcutta-27.
31. M/s Asiatic Oxygen & Acetylene Co. Ltd., 8, Dalhousie Square East, Calcutta.
32. M/s Firestone Tyre & Rubber Co. (India) Ltd., 28, Central Avenue, Calcutta.
33. M/s Goodyear Tyre & Rubber Co. (I) Ltd., 60, Chowringhee Road, Calcutta.
34. M/s India Tyre & Rubber Co. Ltd., 1, Waterloo Street, Calcutta-1.
35. M/s Dunlop Rubber Co (I) Ltd., 52-B Free School Street, Calcutta.
36. M/s National Insulated Cable Co., Stephen House, Calcutta.
37. M/s Burmah Shell Oil Storage & Distributing Co. (I) Ltd., Post Box No. 360, Calcutta.
38. M/s Standard Vacuum Oil Co. Ltd., 6, Church Lane, Calcutta.
39. M/s English Electric Co., D-3, Clive Buldings, Calcutta-1.
40. M/s Asbestos Cement Ltd., P.O. Muland, Bombay.
41. M/s Orissa Cement Ltd., Rajgangpur.
42. M/s Indian Iron & Steel Co., 12, Mission Row, Calcutta.
43. M/s Tata Iron & Steel Co., 23-B Netaji Subas Road, Calcutta.
44. M/s Protos Engineering Co. Private Ltd., 24, Chittaranjan Avenue, Calcutta.
45. M/s Industrial & Agricultural Engineering Co. (Bombay), 43, Forbes Street, Bombay.
46. M/s A.C.E.C. (I) Ltd., 96, Apollo Street, Fort, Bombay.
47. M/s Jessops & Co. Ltd., 63, Netaji Subhas Road, Calcutta.
48. M/s Escorts (Agents), Pratap Buildings, New Delhi.
49. M/s Indian Hume Pipe Co. Ltd., Construction House, Ballard Estate, Bombay.
50. M/s Electric Construction & Equipment Co. Ltd., 35, Chittaranjan Avenue, Calcutta.

little are the firms supplying petrol, oil and lubricant, namely, Burmah Shell, Standard Vacuum and Caltex. These firms have played an important part in the construction of the Project.

A list of firms and contractors associated with the Project is in Statement IV. A review of the quantum of work and the amount of supplies made by various contractors and firms indicacates that out of the estimated cost of Rs.70.78 crores, these firms and contractors have been responsible for a turnover of nearly Rs.37 crores or half the total outlay. When the history of the Hirakud Project is written, the role played by its contractors should find an important place in it. In projects of such collossal magnitude, apart from engineers and finance and accounts people, hundreds of others contribute their share. Apart from finding a livelihood for themselves they join the forces of Govenrment in building up such great ventures which lead to the country's prosperity

A brief passing reference to the systems of contracts prevalent on the Project would not be out of place here. They are:-

1. Work Order
2. Agreements on standard PWD forms
3. Purchase orders.
4. Special agreements not conforming to any standard pattern.

Work orders are generally issued for small items of work at scheduled rates or at a percentage below the schedule to registered contractors. These are mostly employed for supply of labour or material, for earth work, excavation, placing concrete, carriage, supply of sand or stone, hadling cement from wagon to godown etc. In the past there were some instances where even important works were let out on work orders. But this led to a lot of difficulties and since 1953, the system of work orders for major contractors has been almost abandoned.

Agreements are entered into between the competent authorities of the department and the contractors in standard P.W.D. forms after inviting competitive tenders. In this, the contractors have to deposit an earnest money while tendering for the work and later certain amount as security and also stick to definite programme of execution. The department on its part provides certain safeguards to the contractors in matters of payment, providing facilities such as controlled commodities like steel and cement, equipment, etc. The agreement also provides, in case of dispute, for aribitration between the two parties. The value of these agreements varies from a few thousands to several lakhs in most of the cases, and in one case to even Rs.1,11,60,226/-.

The purchase orders are issued for the purchase of stores and equipment, spares for machinery, petrol, oil and lubricants. These are issued either at the rates contracted by the D.G.S.D. on behalf of the Government or after obtaining quotations from manufacturers or firms.

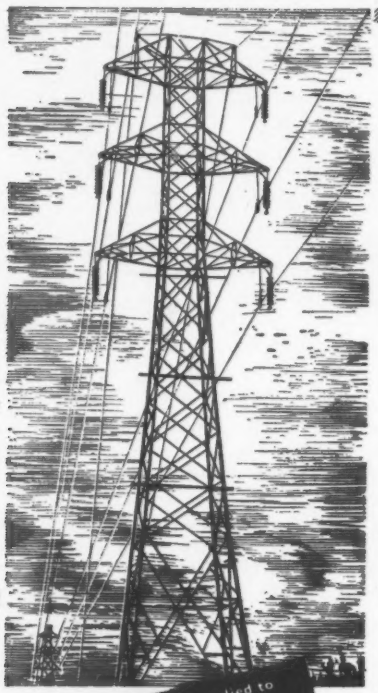
Special agreements are excuted in the case of supply of equipment or services of erectors etc. Most of the machinery and equipment on the electrical side have been purchased through the agency of D.G.S.D., Government of India, who, after inviting global tenders issue what is known as "Acceptance of tender", which is a contract for supply of equipment and at the same time provide certain guarantees. The services of erectors are obtained by supplemental agreements in non-standard forms, ratified in advance by Government.

List of Class I Contractors of Hirakud Dam Project

1. M/s associated Industrial and Engineering Corporation Ltd., 14 Bhag Road, Madras—17.
2. M/s Burma Construction Co., P. O. Burla, District Sambalpur, Orissa.
3. M/s Daya Bhimji, Thumasar Road (M.P.)
4. M/s Kalinga Construction Co., Ltd., Post Box 51, Sambalpur.
5. M/s Gobind Ram and Sons., Hospet Bellary Dist.,
6. Shri Lal Chand Kalra, P. O. Burla, District Sambalpur, Orissa.
7. M/s Master Construction Co., 40-C Cannaught Place, New Delhi.
8. M/s MeCkenzies and Co., Sewri, Bombay—15.
9. M/s Prem Singh & Sons., P. O. Burla, District Sambalpur, Orissa.
10. M/s Raipur Provincial Engineering Company, House No. 11/2564 Bargarh P. O. Orissa.
11. M/s Textile Machinery Corporation Ltd., 8, Royal Exchange Place, Calcutta.
12. M/s Tehla Ram Khushrang, P. O. Burla, District Sambalpur, Orissa.
13. M/s United Construction Co., 4, Commercial Bldgs., Netaji Subhash Road, Calcutta—1.
14. M/s Verma & Ranade Ltd., Janma Bhoomi Chambers, Fort Street, Ballard Estate, Bombay—1.
15. M/s Bedi & Co., Ltd. Hirakud.

Important Items of Civil Works Carried out by Contractors

	Amount (as per estimates) Rs.
Excavation of foundations for Right Side Dam.	27,20,4000
	9,47,400
Excavation of foundations for Left Side Dam.	19,24,575
Manufacture of Aggregate	90,32,329
Masonry for Power Dam and Transitions.	2,28,74,494
Graded Filter and Rip Rap for Left Earth Dam.	43,43,576
Graded Filter and Rip Rap for Right Earth Dam.	1,30,73,795
Spillway Bridge.	6,13,390
Construction of Right Dyke.	1,71,56,400
Buildings.	2,00,00,000
Graded filter and Rip Rap in Gap I.	10,04,229
Construction of Gap II.	6,00,000
Construction of Left Dyke Gap III.	19,00,000
Construction of Left Dyke Gap IV.	42,00,000
Construction of Left Dyke Gap V.	8,00,000
Canals.	6,68,59,000
Roads in Project Area.	16,42,000
Diversion Road.	22,50,000
Jharsuguda Road	7,50,000
Supply of Labour for placing Concrete in Dam.	18,26,174
TOTAL Rs.	17,45,17,762



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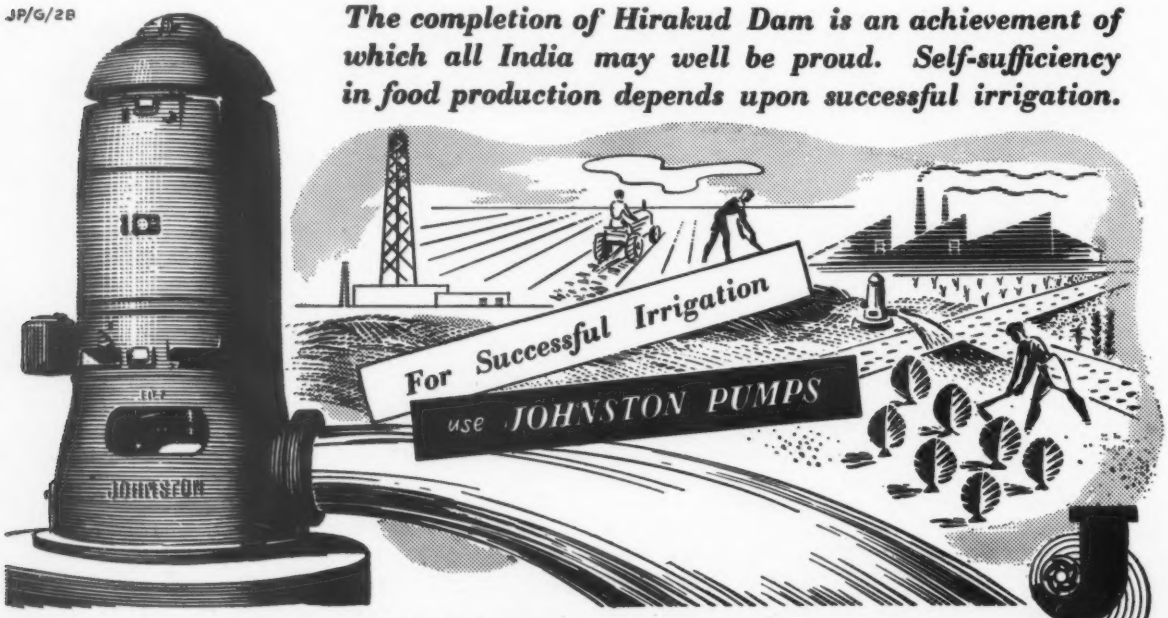

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Labour Welfare in Hirakud Dam Project

By
R. M. SINGH,
Labour Officer
AND
C. M. MOHAPATRA,
Labour Welfare Officer

R. M. SINGH

The Hirakud Project employed more than 30,000 workers at the peak period of its activity. These workers came from many places of India; towns and villages far away from their homes. The resulting psychological unsettlement has been the cause of many a labour trouble in such construction sites. The following contribution gives an idea of the problems that the administration has had to face with regard to the management of labour as well as its welfare such as housing, sanitation, water supply, medical facilities, education, etc.

Organisation of welfare measures in an established industry is comparatively easy, because there the entire programme is taken up on a long-term basis and under limited conditions. But in a huge construction work as the Hirakud Dam Project, extending over a vast area, the circumstances are distinctly different.

It is because in the first place, these multipurpose projects in justification of their title, at once require a massive force of workers, both skilled and unskilled, with multifarious trades and abilities. The mobilisation of such a huge force with varied skills being beyond the resources of a single state, they have to be recruited from the entire length and breadth of the national boundary and, at times, beyond it.

Secondly, the nature of work being seasonal, it entails the liability of seasonal employment, subsequent retrenchment and re-employment.

Thirdly, there is, side by side, two classes of employers ; Government and Contractors, with two different sets of rules governing the conditions of employment.

In spite of all these pecularities, the progress achieved in organising these highly hetrogeneous groups of floating masses into organised life have been spectacular in the Hirakud Dam Project. The management in the Project have consistently viewed the problem of welfare among their workers with utmost human considerations and as a result the progress of execution of the Project have always kept pace with the schedule and many times gone ahead of it due to increased productivity of the labour in all sections of the work.

In September, 1953 a Labour Officer from the Central Pool of Labour Officers was posted in the Project. The strength of the workers having been greatly increased, the project authorities appointed another Labour Welfare Officer in the project in 1955 to look after the problem of welfare. In addition, two Labour Inspectors from the Ministry of Labour were posted in the project to help the management in implementing all labour regulations. But due to substantial completion of work in the project they have been withdrawn by the Chief Labour Commissioner, in August, 1956.

A brief enumeration of the measures adopted to better the lot of workers in this project are given in the subsequent paragraphs to help in forming a general idea of the work done in this field.

Position of Employment & Conditions of Service

Construction of the dam connotes different types of working which may be categorised as concrete works, masonry works, earthwork, erection of power house and running transmission lines. All these works entail use of different types of machines and men to handle them, with a host of manual labour.

Source of recuitment for the departmental workmen has remained mostly the Employment Exchange. In early stages of construction there has been some diversion from that source and recuitment was direct. The department recruits unskilled hands directly in view of expendiency of works.

In rainy season when works cannot be conducted in open air, it becomes necessary to lay off a number of hands. After the rains where works are undertaken preference in recruitment is given to those who were laid off in slack seasons.

Below is a table giving employment position during the peak seasons of the year 1955 and 1956.

	Unskilled	*Skilled*
March, 1955		
Departmental ..	6,152	4,566
Contractors ..	24,014	3,102
March, 1956		
Departmental ..	9,037	7,768
Contractors ..	23,703	2,986

In promotional matters the guiding principle has been one's good work combined with length of service and experience gained by him in his trade.

The laid-off hands are offerred alternative employment and are transferred from one section to the other subject to availability of employment.

Wages which have been fixed on this Project are very favourable. They compare much higher with those paid in the State of Orissa for the same category of workmen. Construction sites, as is known, always entail higher cost of living and these indices

have played significant role in fixation of wages here.

On a comparative graph, an unskilled male and an unskilled female earn Rs. 1/8/- and Re. 1/- respectively per day in the Project whereas, their counterparts in the State get -/12/- and -/8/- respectively. There are instances where female mazdoors have earned Rs. 1/12/- to Rs. 2/- per day while working on piece-wage-system under contractors.

Overtime allowances are paid in the factories at double the normal hourly wages in accordance with the Indian Factories Act, but in other sections of work the over time wage are paid on the principles as decided by the Government of India ; either the usual hourly wages or benefit of grant of equal number of hours of rest.

Working Conditions

Our working is in the open except in factories. Rest sheds have been provided whereever possible. Adequate drinking water supply has been maintained by installing "water centres." During the hot spell of summer when temperature rises upto 120° F arrangements are made to supply ice-cooled water in certain sections and in winter free supply of tea is made to men on machines. First Aid posts have been placed and hardly there will be a work site from where such posts will be a couple of 100 yds away. Provision for latrines and urinals where found necessary has been made. For facilitating work at night flood lights are fixed all over the work sites.

Many of our operations are considered hazardous. Machines, use of blasting materials in stone quarries, automobiles working at high altitude etc., have been responsible for greater number of accidents. In the year 1955, 418 cases of accidents were recorded, out of which 34 proved fatal as against our total average working strength of 30,000 hands.

As a measure of prevention, there is a safety engineer on electrical side and his counter part on civil side also. They advise the safety means to avoid accidents.

Hazard of dust has been controlled by continuous watering of dust raising sources and nasal masks have been supplied also as protection. Such masks were also supplied to workmen engaged on carriage loading, unloading and stocking of cement.

Against hazards of electricity men have been trained in Resucitation Drills. Public carrier automobiles have also claimed certain percentage of accidents. In these cases with assistance of local Transport Authorities, vehicles of safe year's models have been allowed to ply and their speed has been controlled with periodical supervision and check on their running and maintenance. For our operations on earthmoving machineries goggles were provided as a means of protection against glare of the sun. Only licenced blasters are allowed to work in quarries and periodical check is maintained. Every scaffolding, ladder or stair case are examined by the engineers periodically in regard to their stability and suitability for use.

Welfare Measure

Labour is not a commodity and it requires human touch at every stage of his progress. In the light of this principle and considering the massive force of 30,000 on average employed on this project, the task of providing adequate amenities for their welbeing assumes the shape of a baffling problem. This is not because it is an industrial organisation but because it is a human organisation comprising a cross section of humanity of hetrogeneous groups with different languages, customs and traditions. Although in a project much cannot be done on a permanent basis, human needs of the workers who directly work in the department and indirectly through the contractors must be satisfied ; for men are not angered by mere misfortune, but by misfortune conceived as an injury, and the sense of injury depends on the feeling that a legitimate claim has been denied. To this maxim the management in the Hirakud Dam Project has always addressed themselves. This has resulted in stupendous progress in completion of the project much ahead of the scheduled date with 38 million of cft of concreted masonry and 1,386 million cft of earthwork.

Housing

Out of an average of 10,000 workers on departmental strength, accommodation have been made available for about 7,000 and some come from the near-by places or stay with their friends and relatives. The Project authorities have constructed 2,673 houses spread over in 8 different colonies. All these colonies are constructed on high levelled lands and are set on the picturesque landscape with river by the side and hills all around.

Type of Accommodation

L.H.—It consists of one room of $8' \times 10'$ with a small varandah and a partition which serves the cooking place. 10 such rooms are contained in a block.

H— This type has only one room of $12' \times 10'$ dimension and a small verandah.

G— This type of accommodation consists of one room of $12' \times 10'$, a verandah of $12' \times 5' \times 7'$ with a kitchen and courtyard measuring $20' \times 12'$.

I.G.— In this type of accommodation though there is only one room of $14' \times 12'$ dimension, it has a verandah in front and other one in the back of the room. A cooking place and bath room with latrines are there with a courtyard $20' \times 12'$ in the back.

F— This one is a two roomed accommodation. Rooms are of $12' \times 10'$ dimensions. It has a verandah in the front. It has one such at the back. It has a store room of $12' \times 10'$. It has a kitchen of $8' \times 6'$. It has bath room of $7' \times 6'$. It has a latrine also.

Light

Street lights are provided in each colony. In one of the colonies of 'H' type there is supply of electricity to individual quarters. In other 'H' and L.H. type colonies lighting of the individual quarters was not considered safe. However, other accommodations as listed above have electric lights and 'F' type ones have one fan in each.

Water Supply

Filtered water supply is maintained in the colonies free of cost through a net work of 453 taps for six to seven hours a day in three different shifts. The colonies where pipe lines cannot run water is supplied in storage tanks and these are regularly filled by the water lorries. Wells have also been sunk in addition to supplement the need. For two of the main colonies at Burla and Hirakud special filtration plants have been installed to keep up unfettered supply throughout the year.

Community bath rooms with adequate privacy for males and females separately with 8 to 10 taps in each are provided in colonies.

Latrines

There are in all 650 seats of community latrines on a very moderate scale of 1 seat for 11 perons, These figures do not include the number of latrines in 'Twin G', 'G' and 'F' type accommodations. In labour colonies service type latrines have been mostly replaced by latrines as improved by the All India Institute of Public Health and Hygiene, Calcutta, for rural use. To keep them more clean a water seal is attached to each one of the seats which control the bad odour and help the night soil to decompose down in the pit.

Sanitation and Public Health

There is an organised Public Health Department. Its function is to maintain the colonies clean from every sanitary points of view. In each colony one would find dustbins for storing garbage etc, which are transported away by gangs of sweepers in conservancy trucks to farther off dumping places. Similarly, night soil is also carted away. Sufficient use of disinfectants is made.

Drainage system in the colonies is quite satisfactory and the drains are all paved to flow off to low lands, where accumulated water is treated against all possible infections.

Antimalarial activities, larvic and otherwise, are conducted to best possible satisfaction.

Preventive measures against spread of epidemics are also conducted through free compulsory vaccination and inoculation.

Medical Facilties

There are two self contained hospitals at Burla and Hirakud with facilties of 56 indoor beds and 12 maternity beds with two branch dispensaries at Chiplima and Bargarh. There are 9 qualified Assistant Surgeons including 2 Lady Assistant Surgeons under a Chief Medical Officer. There are different wards for females and males and seperate wards for infectious diseases. There is an X-ray plant, the second of its kind in Orissa. Facility for free radiological treatments for employees exists. Pathological and clinical laboratories are attached to these hospitals. There is a Family Planning clinic. Treatment of all descriptions and provided free to workers and their families.

Thus the Project ensures free medical facilities both preventive and curative to all the workers engaged in the construction.

Education

There is a High School inclusive of primary classes at the Project head quarters at Burla for the benefit of the employees. It is a co-educational institution with about 1000 students on roll. The medium of instruction is both Hindi and Oriya. There are 22 teachers in all including 5 lady teachers.

Children receive education by payment of very nominal fees. The school has the facilities that a modern institution of the type can boast of. The school is affiliated to Orissa Board of Secondary Education.

In addition to this there is a Middle English School at Hirakud in charge of a trained graduate Head Mistress assisted by 6 other teachers.

In 3 of the major labour colonies there are three primary schools where free education is imparted to the children of the workers residing in those colonies.

Since July, 1956 a University College of Engineering and a Polytechnic Institute have been established in Burla and Hirakud respectively.

A Survey Class under guidance of a trained Survey Master has been established in Hirkud Island where workers in their off-times are imparted training in survey.

Under the drive against illiteracy we have a number of Adult Education Centres. Due to completion of work in different section of the Project we have only 4 such centres at present.

The Project in total spends Rs. 1 lac per year for the purpose of education of the children of the employees.

Workers' Library

There is a library with about 500 books on different subject which the workers utilise to their benefits.

Daily news-papers in Hindi, Oriya and English are supplied to every Sramik Kalyan Kendra and there are six such centres existing in groups of Colonies. A Hindi fort nightly Magazine 'Kamgar' published under the auspices of the Union Ministry of Labour is also provided.

Games & Sports

In each of the labour colonies in the Project a set of Volley Ball has been supplied by the Project authorities and all types of outdoor games are organised among the workers. To encourage sports annual meets are held every year on Independence day and prizes are distributed to winners. Cost of sports and prizes are borne by the Project.

In addition, due encouragement is given to teams of the workers to play in the local foot-ball tournaments. In recent month our workers team have participated in the local league tournament and have been declared runners up.

Cultural and Recreational Facilities

Cinema shows are given every month in our labour camps with full length feature films. Documentaries and other educative films are shown free of cost. These shows are given through our own Projectors purchased for the purpose. We have 3 projectors of

16 MM size and have our own Cinematography and still photographic sections to accelerate the programmes.

A public Cinema house has also been opened free from entertainment tax which screens films in different languages for the workmen.

Dramas and variety entertainments are staged by our workers in different languages from time to time with grants from the Chief Engineer. There are two Open Air Theaters with sitting accommodation in Burla and Hirakud with arrangement for stage and lighting.

Welfare Centres

There are six Welfare Centres (Sramik Kalyan Kendras) in different labour colonies of the Project. These kendras form the nerve centre of all welfare activities in Labour Colonies. This is a meeting place for the workers, newspapers are read, religious discourses are conducted, cultural shows are held. Primary School and Night Schools are also carried out in these centres. The Project has a sanction of Rs. 3,500/- per annum for running and maintenance of these centres. There are Welfare Committees formed with five prominent members of each of the colonies which is responsible for successful running of these centres.

Creches

The Department do not engage female Mazdoors, but the contractors do employ them. Thus, where it has been warranted, creched have been opened to keep working mothers free of botherations of looking after their babies. These creches are liable to be closed as the work sites are abolished and it happened in two such cases. However, at present two creches are functioning. In these creches, milk is supplied to the children free. On occasions garments have also been distributed to them free of cost. There are arrangements for toys for play; and for teaching alphabets under a trained creche attendant.

On occasion of festivals and days of national importance sweets are distributed amongst children of the workmen in the colonies.

Ladies from the families of the officers have also not lagged behind in lending a hand for the cause of workmen. They, in a squad move in labour colonies, mixing with the women folk, teaching them better ways of sanitation and living. They also had opened a 'Knitting Class' in one of the colonies and by free supply of wool and knitting materials, have been teaching the desirous one to knit garments.

Training Facilities

Hundreds of workmen have been trained to operate heavy earthmoving equipments. The job to operate these machines is quite a new feature in our country and it may be said with pride that we have turned out highly experienced operativs, fitters and mechanics for these machines, who at any time may face their future with confidence and in doing so we have created a fleet of technicians for fearlessly undertaking other projects. Our Dragline Operators at Durgapur in D.V.C. area may be cited as an example.

Transport to and from work site is provided free of cost to our workmen whose duties command such facility. There are 6 buses running exclusively for this purpose in each shift.

Postal Facilities

Apart from two main post offices serving the permanent colonies ; for facilities of our workmen, two branch post offices were arranged to function in two main groups of colonies ; at convenient places post boxes are fixed in each colony.

Police protection is also provided. The Project is maintaining a security force apart from two main civil police stations There is another police outpost in one of the biggest groups of Labour Colonies.

Marketing Facilities

In each of the main colonies there are fully established markets for almost all the necessities of daily life. Haat is conducted in each of the colonies on sundays.

The workers are governed by service conditions prescribed under bi-lateral terms of agreement in regard to Health and Hygiene, both off and on the site of works. Payments of compensation in cases of injuries, arrangements of creche, First Aid Posts, Rest Shelters, Maternity Benefits, drinking water, bathing and washing facilities, latrines and urinals, sanitary and conservancy arrangements holidays and rest days etc., guarentee of wages, payments for overtime workings and protection against malpractices in payments etc ; all possible control is exercised to keep our working masses content and far away from politicial exploitation.

Monthly Labour Bulletin

To instill the sense of oneness and to make our workers realise their responsibility in the national war against poverty and pestilence a monthly labour bulletin is published by the administration in Oriya, Hindi and English. This announces all measures of welfare adopted for the benefits of the workers. This is a unique experience of this Project, which has been able to bring labour and management to a very close proximity and there exists a great harmony in our relationship.

Miscellaneous Amenities

There is a grant of Rs. 5,000/- placed at the discretion of the Chief Engineer to be spent on benefits to workmen if expenditure of the items are not covered under appropriate heads of accounts. Adequate monetary assistance has been provided out of this grant to families of workmen if the bread earner has expired due to certain accident on the project ; and also to meet the funeral expenses of the deceased. The latter expenditure as statutorily provided under the Workmen's Compensation Act as deductable out of the total amount of compensation payable. But this is provided as ex-gratia. Expenditures on distribution of sweets to children of workmen as said above, supply of knitting materials, distribution of clothes to children in primary school and creches, Cinema shows etc., have been made out of this fund only.

There was a grant of Rs. 6,000/- for supply of a cup of tea to each operator of heavy earthmoving equip-

ment and other running staff during spell of cold weather. Tea was supplied this year and the rest of the grant has been approved to provide a grant of Rs. 500 each to canteens of the workmen if it is run on co-operative basis.

Three canteens started functioning on co-operative lines. One has been closed because of closure of that particular work-site but yet other two are working. One of these canteens accrued some profit and part thereof has been spent on community feeding on a festive occasion. Profits have been approved to be spent in likewise manner. In these canteens, light, water, furniture, accommodations and initial expenses are provided by the management.

There is a co-operative society. It has two main branches, and three sub-branches in the heart of labour colonies to cater provisions and other consumer goods at cheaper rates. Accommodation and light arrangements to these stores are provided free.

Cultural and recreational meets have become almost a daily sight when folk dances, devotional songs, kirtan and bhajan etc., are conducted generally in evenings in camps.

Trade Union is almost non-existant. There is only one Union known as Hirakud Mazdoor Congress affiliated to I.N,T.U.C.

Industrial relations have been very cordial. Since January, 1954 there has not been a single instance of even misunderstanding. The Management has been fully alive to interests and well beings of the workmen and slightest defects have been rectified immediately. Workers have also lived up to their responsibilities and duties. They have given their fullest support and co-operation in completing this giagantic monument.

Amenities for Contractor Labour

As evident from the statistics provided in the article a considerable numbers of workers are employed in the project by the contractors and it would not be fair not to say a word about them. As compared to the conditions of employment under department the picture of labour under contractors may appear less dignified but a proper study of the circumstances can help better understanding of the problem.

In the first place the Labour under contractors are recruited through their sardars from the neighbouring areas and, as such, are subject more to the whims and caprices of their sardars. These sardars in their efforts to have maximum gain migrate from one employer to other without any hesitation and workers under them assumed the shape of a floating mass.

Secondly, these workers having their root in the villages, usually take employment outside their field as seasonal and during sowing and harvesting seasons they call back on their lands.

Thirdly the works on contract being scattered; a set of workers under particular contractor has to shift constantly from place to place.

Under the circumstances no permanent colony for the contractors have ever been a possibility. However the contractors provide materials for hutments, on high levelled lands selected by the project authorities. Filtered drinking water and street lights were provided wherever possible to these temporary colonies free of cost by the department. These workers enjoy medical and public health amenities in par with the departmental workers.

In far off work sites the wells are sunk to augment safe water supply. A whole time doctor for Labour Welfare visits all these camps every week to check the standards of general health and contractors have their stock of medicines to meet the immediate needs of workers working in mass in far off places. For the benefit of the working mothers, creches wherever necessary have been opened. Adult schools and primary schools are also functioning in bigger colonies laid by the contractors.

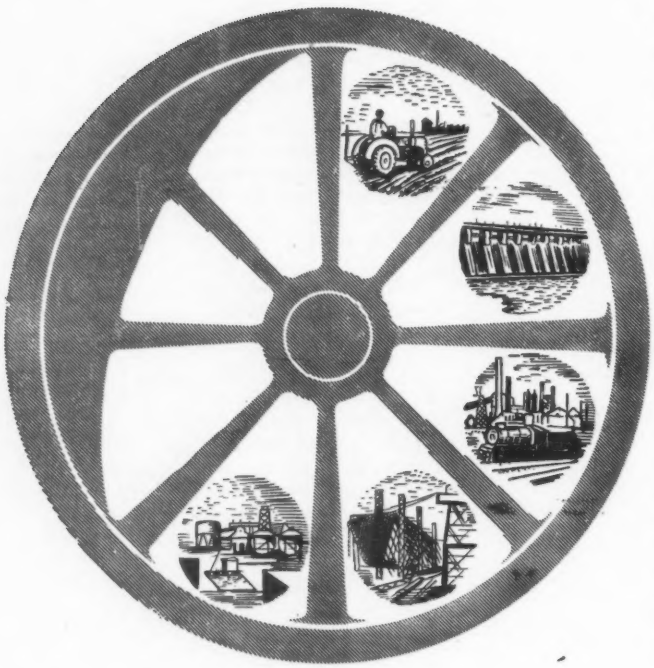
Implementation of Minimum Wages Act, fair wage clause, Workmen Compensation Act and the Contractors labour regulation in the lines of C.P.W.D. are strictly adhered to. These ensured fair play and justice to this vast mass of workers employed under our contractors.

But much as we wish, nothing more could be achieved in this sector for various shortcomings inherent in contract system of work.

Conclusion

In the conclusion it would be helpful to stress the need of fresh assessment of the problem of human welfare in industries in general and multipurpose projects in particular with context to the fact that, the liberation of mother-land, in its wake, has brought a general upsurge and re-expression of values and the way of life among the masses. It becomes more pertinent to recognise these aspirations on the part of our people, particularly at this transitional phase of our national progress, when the old policy of laissez-faire with its halting and hap-hazard industrialisation is yielding place to a dynamic policy of planned industrialisation. If these twin objects of rapid national development and increased social justice are to be achieved, the issue of the project workers can not be isolated and every effort should be made to give them a sense of stability in their employment and a nation-wide mobilisation of the technical personnel employed in such huge projects should be taken up immediately to absorb them in gainful employment elsewhere after the completion of these projects. This will give them hope and confidence to face the bleak uncertainty over future and would ensure for the nation, an army of highly technical personnel to be commissioned at very short notice for all such major works in future.

THE WHEELS OF THE PLAN



Our country is spending Rs. 7,200 crores in the Second Plan period on development programmes. Production in fields and factories will be stepped up to a still higher level, our basic heavy industries will be expanded, and new industries established. An enormous flow of raw materials to factories and workshops..... a ceaseless stream of finished products to internal markets and ports—that is the charge ahead of our country's transport system. India's blue-print for prosperity is keyed to her transport... and the Railways will bear the burden.

Help the Railways—Your Railways—Serve You Better

EASTERN RAILWAY

Visitor's Guide to Hirakud

By

R. RANGACHARI, B.E. (Hons).
Executive Enginieer, Hirakud Dam Project

AUTHOR

Now that the longest Dam in the World is complete it is a sight to see. Orissa is an ancient land associated with Konarak, Puri, Bhubaneshwar. But now people from far and near will come to Orissa not only to see these ancient monuments but also the new monument of Hirakud. This contribution describes the chief items that one should visit in and near Hirakud.

Hirakud is nine miles upstream of Sambalpur town. There are two construction colonies, one on each bank of the river. The Left Bank Town is called 'Hirakud' and the Right Bank Town is called 'Hirakud Colony', to distinguish it from the other town. It is also known as 'Burla' after the village in which it has sprung up. Both the towns are 9 miles from Sambalpur and are connected by good 'black top' roads.

Sambalpur, the head quarters of a district by that name, can be reached either by road or by rail. The National Highway No. 6 from Calcutta to Bombay passes through Sambalpur. Sambalpur can also be reached from Cuttack by a good road 175 miles in length. There are numerous rest houses and inspection bungalows throughout this length for visitors to halt and rest. A train service connects Cuttack with Meramandali on the Cuttack-Talcher Line. Orissa State Transport services connect Meramandali and Sambalpur. The Bus Terminus is at Meramandali Railway Station itself and every train from Cuttack has connecting bus service available immediately. Reservation on these bus services can be made from Cuttack station itself.

Also one can reach sambalpur by train via Jharsuguda, a station on the Bombay-Calcutta Main Line of the South Eastern Railway. A through coach is attached from Calcutta to Sambalpur on the Calcutta-Bombay Mail, for the convenience of passengers coming to Hirakud. From Sambalpur, Orissa State Transport buses frequently run to Burla and Hirakud. Taxies (Private as well as State Transport) are available at Sambalpur.

On the left end of the Dam an airstrip has been constructed for the convenience of visitors coming on chartered flights. Prior intimation has to be given and permission obtained from the Chief Engineer, Hirakud Dam Project to land in this airstrip. About 30 miles from Hirakud there is another aerodrome at Jharsuguda. Good motorable road connects Jharsuguda and Hirakud.

Rest House

There are Rest Houses in both Hirakud and Hirakud Colony. Rest Houses, Chummeries and Hostels, fully furnished in modern style, are available on both the sides. A Circuit House located on the top of the Right Side Observation Hill, and commanding a full view of the Dam and the lake has been built for use by important guests. Reservation is made by prior intimation to the Project authorities (Chief Engineer, Hirakud Dam Project) who can also arrange for transport from Sambalpur Station to Hirakud or Hirakud Colony at nominal charges.

Circuit House and Rest Houses are available in Sambalpur town also, in which reservation can be made through the Deputy Commissioner, Sambalpur or Executive Engineer, Orissa P.W.D., Sambalpur.

Salient features of the several works and an itinerary that a visitor should generally follow are detailed below.

The Dam

From anywhere in the project area the great barrier across the Mahanadi can be seen, towering across the blue sky line, standing as a monument honouring the tireless work of the millions of workers striving to improve the lot of their fellowmen. The Main Dam is 15,748 feet long out of which a total length of 3,768 feet will be in masonry and concrete to serve as Power Dam and Spillway and the remainder will be of earth. Generally a visit may commence with a trip to the Right Side. One can drive up straight to the Right Side Observation Hill, from where, standing on the view tower, he can have a panoramic birds' eye view of the whole project. From Right to the Left the Power Dam, with the Power House standing on the rear, immediately abutting the hill is seen ; in continuation of this Power Dam, the Right Spillway spans across the Right Channel of the River. Far beyond, the Left Spillway spanning across the Left Channel is also seen. The two spillways are connected together by the Earth Dam. On the other side another portion of the earth dam connects the left spillway to the left abutment hill. The Right Dyke connecting the Chandli Dungri Hill (which is the Right Abutment Hill of the Main Dam) and Balrpahar Range is also seen from here.

The Reservoir formed by the Dam will spread over 288 sq. miles. The gross storage capacity is 6·6 million acre feet of which 1·88 million acre feet will remain as dead storage. From the observation point one can either drive down or walk down the steps to the Power Dam.

Powep Dam

The Power Dam accommodates seven penstocks of

A grand view of the Reservoir as seen from the left abutment.

23 ft. to 25 ft. diameter out of which four will be used immediately now, and the remaining will be kept for future expansion. The penstocks cannot be seen now as they are already buried in the dam. The 25 ft.-diameter penstocks are probably the largest in Asia and the Far East.

The Power House is situated immediately on the rear of the Power Dam. This houses the giant turbines and generators which produce the power. In the first stage two generators of capacity 37,500 K.W. each and two of 24,000 K.W. each are installed, thus aggregating to a total installed generating capacity of 1,23,000 K.W. Behind the Power House is a control room, which is the nerve centre of all operations in the Power House. Every operation is being watched and controlled through the control panel here. The generators are started and stopped, gates lowered, all through finger tip control here.

The elevator tower houses the elevator connecting the Power House with the top of the dam. The maximum height of the masonry dam is 200′ in the Power House portion.

Spillway

Spillways are concrete dams pierced by low level sluices with suitable arrangements for opening and closing by gates. Also the top of the dam will allow surplus waters to spill over the crest during flood times. The crest gates have been provided on the top and by operating these water can be either stored or allowed to spill.

A total of 64 numbers bed level sluices 12′×20′4″ are provided for in this dam. The enormous number of sluices will help in passing down the early silt laden floods. The impounding will be done after August, when the flow in the river is comparatively less burdened with silt.

The sluice gates are raised or lowered by hoists in the sluice gallery.

A quantity of 23 million cft. concrete was involved in the Spillways. The concrete for this came from the two huge batching and mixing plants (one on the right side and one on the left side) of 12 and 8 cyd. mixer capacities fed with aggregates crushed mechanically and cement being fed also by mechanical equipments. Diesel loco units hauled two to three cyds. buckets carrying this concrete and cranes dumped the concrete in situ.

As water will flow over the crest of the dam during surplussing times the spillway bridge connects the non-spillway dam on either side.

Earth Dam

Passing over the spillway bridge one reaches the earth dam, the maximum height of which is 195 ft. In forming the Main Dam and Dykes, the earth work involved was enormous involving digging, hauling and compacting earth to give a compacted quantity

A panoramic view of the dam and the lake as seen from the Right abutment. Please note the Power Dam on the downstream side and the water intake structure for the Power Units on the upstream side.

The Power House built on the rear of the Power Dam—an exterior view.

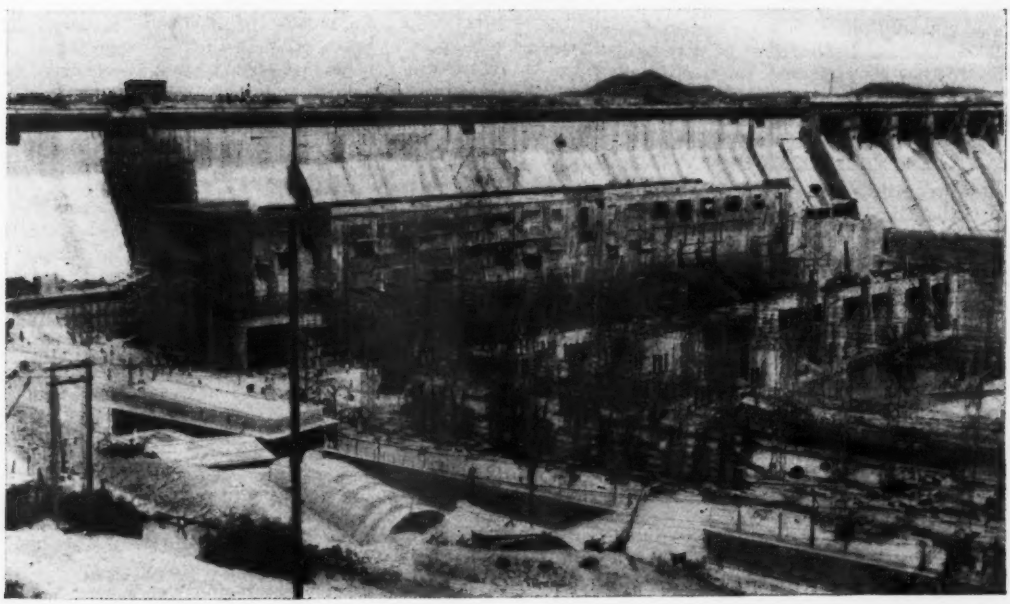


Plate 12—Finished view of German unit and erection work of other units.

of 64 crores cft. (24 million cyds). The huge quantity of earth needed for the main dam had to come from an average lead of two miles. Obviously this job cannot be done by manual labour in such a short time. Huge earthmoving machines like shovels, loaders, scrapers, dumpers etc. were put into operation.

The soil and sub-soil at the dam site (and the dykes) have been examined and the borrow areas were selected to give the suitable material needed. The front side is protected by riprap of suitable thickness over a layer of filter material. The rear side slopes have been protected by pitching and turfing.

A roadway with gentle slope connects the earth dam with the Hirakud Island, on the down stream side of the Main Dam. The Hirakud Island is being developed as a fine garden which will serve as a recreation-cum-picnic centre.

Canals

There are two main canals; one on the right side and the other on the left side. The Right Side canal named the Bargarh Canal is designed to carry a discharge of 4,800 cusecs and will irrigate an area of 3.8 lakhs acres. Taking the area under second crop also, this canal would irrigate 5.28 lakhs acres every year. The canal on the left side, the Sason canal, will carry a discharge of 630 cusecs and will irrigate an area of 62,00 acres. There is also a small canal of capacity 120 cusecs taking off from the left side Gap II. The canal system involves excavation of 75 crores cft. of earth and consists of 552 miles of canals, distributaries and minors.

Bargarh Canal

A good contour road connects the Main Dam with the Right Dyke. After a pleasant drive along the boundary of the reservoir of about 3½ miles, we reach the Right Dyke. The Bargarh Canal takes off from the Right Dyke at RD 29,000. Water is left into the Bargarh Canal from the reservoir through this Head Regulator. 8 vents 7′6″×9′6″ are provided with suitable gates. A motorable inspection road has been provided on the left bank of this canal.

As one passes along this road, he will see the numerous cross drainage works, regulators and distributaries, syphons, aqueducts, super passages etc., in succession. The canal is taken over the various hill streams by aqueducts. The major aqueducts are across the Danta, Jira, Girsol and Ranijhor streams. Small streams which cross the river are also syphoned under. Water is let into the various branches and distributaries through regulators. The Attabira branch, taking off at RD 33 of the Bargarh Canal, is the biggest of the distributaries in this system.

Left Side Canal

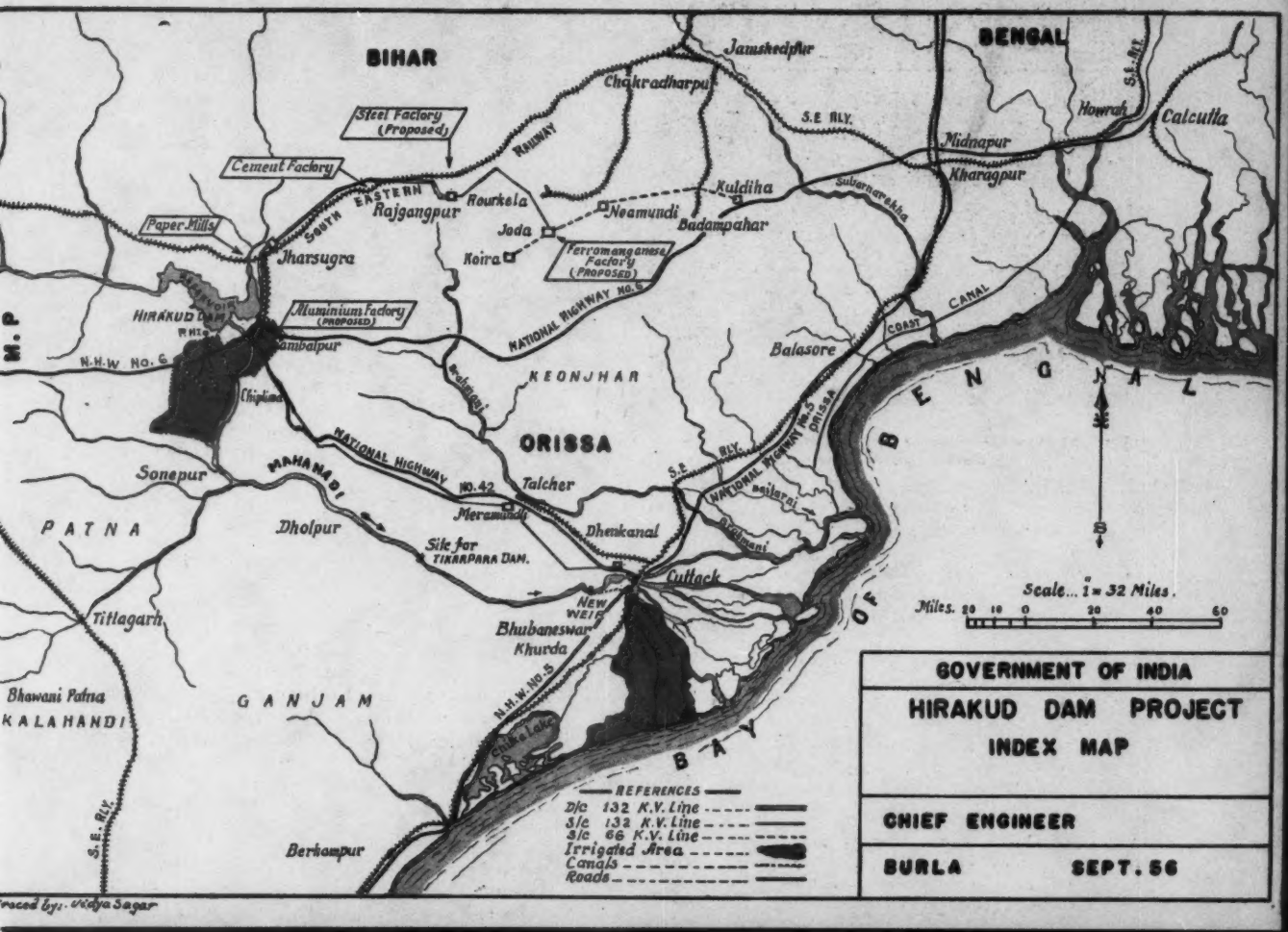
The Sason Canal takes off from the IV Gap. A good road connects the Main Dam (Left side) and all the dykes on the left side. The Sason Canal is a comparatively smaller canal and it serves the ayacut on the left side of the Mahanadi. The Homa and Paramanpur distributaries are the main branches of this canal. The Sambalpur Canal takes off from the second gap and serves the fertile land in and around Sambalpur. The water supply to Sambalpur is proposed to be taken through this canal.

Rehabilitation

Visitors may be interested to know what happend to the people and the villages that existed in the reservoir bed. Consequent to the formation of the reservoir, over 1.8 lakhs acres of land has been submerged. Lands and houses of 283 villages were affected ; a population of 100,000 displaced. 113 villages are fully submerged. The evacuation and resettlement of these people has been no easy task. New areas were reclaimed and new villages created with all the basic amenities like roads, water supply, hospital, schools etc. Minor irrigation schemes were undertaken for their benefit.

Leaving behind their familiar hearth and home, and settling in new localities in new homes for the greater benefit of the community is sentimentally very difficult. But the willing co-operation of the people affected greatly helped the authorities in this herculian task.

New Model Colonies with full amenities have sprung up at Sangramal, Silat, Jargathi, Basiapara etc. The Rampella Artisans camp is on the Sambalpur-Jharsuguda Road on the 14th mile from Sambalpur. The Silat camp is immediately on the downstream of Right Dyke. Basiapara camp is on the 16th mile from Sambalpur on the Sambalpur-Cuttack Road. Sangramal camp is 16 miles away from Sambalpur on the Sambalpur-Ranchi Road. The settlers have been provided with all the basic amenities here. Small streams flowing in these regions have been bunded



GOVERNMENT OF INDIA

HIRAKUD DAM PROJECT

INDEX MAP

CHIEF ENGINEER

BURLA SEPT. 56

Traced by:- Vidya Sagar

A down stream view of the Spillway with the sluices fully discharging. The crane used for placing the concrete during construction may be seen on the foreground.

Earthmoving equipments are at work.

The canal crosses a number of streams on its way. The Girsol aqueduct at the crossing of the Girsol River may be seen.

Land Reclamation Area. Recently resettled villagers busy in constructing houses.

up under minor irrigation schemes to form Kattas which irrigate the nearby lands and feed the village tanks.

Transmission Lines

To reap the full benefits of the project, the power generated must be fully and speedily utilised; and thus the problem of transmission and distribution of electrical energy assumes a crucial role in the project development. The first stage of the Project provides for the erection of 132 K.V. grid sub-stations at Jharsuguda, Chainpal, Chowdwar (Cuttack), Rourkela and Joda and 66 K.V. sub-stations at Noamundi, Kuldiha and Koira. This involves the construction of over 500 miles of high voltage transmission lines. A net work of 11 K.V. and 33 K.V. feeders have been built from the sub-stations by the Orissa State Electricity Department for distribution of power to the ultimate consumers. Various colonies at the respective sub-station sites will house the permanent staff needed for the operation and the maintenance of the power system. As one motors along the Sambalpur-Cuttack road or Sambalpur-Jharsuguda road the transmission lines can be seen almost all through the distance.

Salient features at a glance

RESERVOIR

Fully Reservoir Level	RL. 630.00
Maximum Water Level	RL. 630.00
Gross Storage capacity	6.6 Million Acre Feet.
Dead Storage capacity	1.88 M.A. Feet at 590.00
Live Storage	4.72 Million Acre Feet.

MAIN DAM

Total length		15,748 ft.
Length of Concrete and Masonry Dam		3,768 ft.
On left side	1,640	
On right side	2,128	
	3,768 ft.	
Quantity of concrete and masonry		1.4 Million Cubic Yards.
Length of Earth Dam		
Right Dyke		35,500 ft. in one stretch.
Left Dyke		32,275 ft. in 5 gaps, spanning hillocks.
Total quantity of earth work in Dam		24 Million Cubic Yards.
Maximum height of Earth Dam		195ft. (at the deep channel bed)
Maximum height of Masonry Dam above foundation		200 ft. (Power Section)
No. of undersluices		64 (40 on the left and 24 on the right)
Size of undersluices		12′0″×20′4″ each.
Sill level of undersluices		+510.00 RL.
Crest level of spillway		+610.00 RL.
No. of crest bays		34 (21 on left and 13 on right)
Size of crest Spillway Gate		51′0″×20′0″
Designed Maximum Flood discharge		1,500,000 cusecs

CANAL SYSTEM

Culturable area	15,31,000 acres.
Annual irrigated area	25,39,094 acres.

POWER

Average Head	87 ft.
No of Generating Units	2—37,500 K.W. each and 2—24,000, K.W. each
Lower Power House	3—24,000 K.W. each.

TRANSMISSION AND SUB-STATIONS

Total length of Transmission Lines :	
132 K.V.	418 route miles.
66 K.V.	90 route miles.
No. of Grid Sub-Stations	8 Nos.

ANTICIPATED UTILISATION OF ELECTRIC POWER FROM HIRAKUD BY 1960

Aluminium	50,000 K.W.	Mining Loads.	
Steel	60,000 K.W.	(Barbil, Birmitrapur and Rairangpur)	8,000 K.W.
Ferromanganese	20,000 K.W.	(Collieries Cuttack and other	2,400 K.W.
Cement	5,00 K.W.	Rural and Town	
Paper	3,000 K.W.	Loads	13,000 K.W.

In addition to the works mentioned above, there are certain other ancilliary spots worth visiting at Hirakud. The Research Station (called the Design and Research Division), the Workshop and the Hirakud Stores need mention amongst these. The Research Station is in charge of the quality control of all the works in the Dam and the Dykes. It is just opposite to the Hirakud Rest House. It is provided with up-to-date testing equipment for both soils and concrete. A masonry testing station has also been set up recently to test the strength of rubble stone masonry blocks.

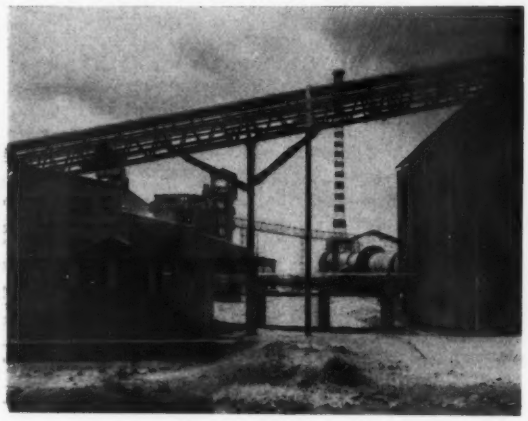
The Workshop

The workshop in Hirakud is well equipped. It is

A view of the Workshop.

responsible for all the maintenance and overhaul of heavy machineries used on the Project. The Sections in it are a pattern making shop, steel structure shop, smithy and welding section. Some spares and tools needed were also manufactured in this workshop.

Adjacent to the Workshop are the Hirakud Central Stores, one of the best equipped in this country.



Rajgangpur Cement Factory. A cement factory with capacity of 500 tons/day was started to serve the project.

Communication

In a work of this magnitude spread out in a large area, communication plays a vital part. To carry the construction material and heavy equipment needed, the Project has got its own Railway system viz. Hirakud Dam Railways with 37.5 miles of Broad Gauge Railway, 12 locos and 534 wagons of 20 to 22 tons capacity each. This Railway is linked with the South Eastern Railway at Sambalpur Terminus. A rail-cum-road bridge of 25 spans of 100 ft. has been built across the Mahanadi. This will have the advantage of serving the future requirements of Railway

Mahanadi Rail Road Bridge.

and National Highway expansion. The construction works were commenced in 1948 and the bridge was completed in a record time by August, 1950.

A Trip Around

The Project area is spread over a long distance, and to see the works in detail, it will take two to three days. Small groups of visitors are conducted through the Project area by obtaining prior permission from the Chief Engineer, Hirakud Dam Project. The Assistant Information Officer stationed at Hirakud accompanies the parties to explain the various features. Large groups of visitors are also conducted around if sufficient advance notice is given to the Chief Engineer. Closed vehicles from the Project Transport or Hirakud Railway Wagons will be made available for their conveyance at nominal charges.

On festive occasions sweets were distributed to the labourers. Photo taken on Independence Day.

The Hirakud Dam Project is the largest multipurpose Project completed after Independence and naturally many would like to visit this place to see the great achievement after the awakening of the modern India.

A visitor to Hirakud can couple this trip with a visit to the other places of interest nearby.

Cuttack, Bhubaneswar, Puri, Konarak are the major places of interest around Hirakud.

Bhubaneswar

Orissa's new capital is situated at Bhubaneswar,

On 7-9-1956 the Chief Engineer, by pressing a button, let in the first flow of water in the Bargarh Canal System—A view of the canal as seen from the Head-Regulator.

which is noted for its historical associations and existing archaeological treasures. The capital has been

built at a site, which was a few years ago full of jungles and wild animals. The master plan of the capital was drawn by Dr. Koenigsburger, an expert and well known architect. It provides for five neighbouring units, each of which will be self-contained so far as schools, shoping centres, play grounds, etc., are concerned.

A large number of temples adorn Bhubaneswar (old town). Most of them have been battered by time and are in ruins—relics of the glory that is past. Others, though partially damages, still remain as gems of the Kalinga architecture.

The temple of Lingaraj towers above all the existing temples here. It is the quintessence of the Kalinga type of architecture and is one of the archaeological monuments of India. In its sculptures some of the best specimens of the Orissan decorative art is to be found. Fine scroll works, which must have taken months of labour are to be seen in some of the images.

Caves of great antiquity are situated at hillocks near Bhubaneswar, Udayagiri and Khandagiri are prominent amoung them. One of the hillocks, about 5 miles south of Bhubaneswar, bears the famous rock edicts of Asoka promulgated in 257 B.C.

Puri

To the sophisticated, Puri is only a health resort, but to the average Indian it is a very famous pilgrim centre. Every year thousands of devotees from all parts of India visit Puri on the occasion of one or the other festivals of Lord Jagannath. The temple here was built during the reign of Ananga Bhima Dev and was completed in 1198 A.D. The main tower is 214′ 8″ from the road level.

First class hotels are available in Puri. A train service connects Cuttack and Puri in the South Eastern Railway. An all-weather road connects Cuttack, Bhubaneswar and Puri.

Konarak

The temple of the Sun God is situated at about 20 miles from Puri to the North East. Grand in conception, and great even in its ruins it stands on a desolate tract of drifting sands. The temple was built in the 13th Century. The Tower of the Main buildings which enshrines the deity has fallen off. The Jagmohan or the hall of audience is the only structure which survives in complete form. The height of the temple is 227′.

"Few buildings in India can boast of such an unrestrained abundance of plastic decoration as this vast structure, every portion of the exterior being moulded and chiselled either in the form of mythical animals, fabulous beings of every conceivable form etc."

A fair weather road exists to Konarak which takes off from the Bhubaneswar Puri Road, near village Pipli. This road is being improved so as to provide access to Konarak at all times.

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Appendix I

TRAIN AND BUS SERVICE TO AND FROM HIRAKUD (MADRAS—HIRAKUD—MADRAS)

Madras — *Hirakud.*

		H.M.	H.M.
MADRAS-CALCUTTA MAIL			
		Mail	*Janata Ex.*
Madras	d	20-25	9-50
Bezwada	a	5-51	21-20
	d	6-20	22-20
Waltair	a	15-40	7,45
	d	16-20	8-20
Vizianagaram	a	17-28	9-45
	d	17-43	10-11
Khurda Road	a	1-29	20-0
	d	1-44	20-15
Cuttack	a	2-49	21-13
CUTTACK-TALCHER BRANCH LINE			
		Passenger	
Cuttack	d	8-46	20-14
Meramandali	a	12-14	23-38

MERAMANDALI—SAMBALPUR—HIRAKUD

125 Miles Road Bus Service connects trains at Meramandali with a change of bus at Sambalpur which is 116 miles from Meramandali.

Hirakud — *Madras*

		H.M.	H.M.
HIRAKUD-SAMBALPUR-MERAMANDALI			
125 Miles Road —Bus Service.			
connects trains at Meramandali.			
CUTTACK-TALCHER BRANCH LINE			
		Passenger	
Meramandali	d	3-8	15-35
Cuttack	a	6-35	17-50
CALCUTTA—MADRAS—MAIL			
		Janata Ex.	*Mail*
Cuttack.	d	8-12	1-9
Khurda Road	a	9-24	2-21
	d	9-39	2-36
Vizianagaram	a	17-38	10-6
	d	17-51	10-18
Waltair	a	19-45	11-50
	d	20-10	12-35
Bezwada	a	5-45	21-30
	d	7-10	22-5
Madras	a	18-35	8-10

BUS TIMINGS

From Meramandali.

	Leaving Meramandali H. M.	*Arriving Sambalpur* H. M.
1st.	00-30	7.00
2nd.	00-40	7-15
1st.	12-00	19-00
2nd.	12-30	19-30

From Sambalpur

	Lvg. Smb.	*Arr. Mml.*
1st.	8-00	14-00
2nd.	8-30	14-30
1st.	19-00	1-30
2nd.	19-30	2-00

Note :—Vizianagaram—Raipur is a branch line covering 330 running miles, which connects the two major main lines of Madras—Calcutta and Bombay—Calcutta. Titlagarh a railway station lies on this line at a distance of 200 miles from Vizianagaram. This Titlagarh is connected with Hirakud by bus en-route towns of Balangir, Bargarh and Sambalpur. Sambalpur is again connected by bus to Hirakud at a distance of 9 miles. There is also an alternative route, which does not take to Sambalpur town but buses are to be changed at Bolangir and Bargarh. This distance is covered by the following routes :—

(*i*) Titlagarh—Bolangir—48 Miles. (*ii*) Bolangir—Bargarh—48 Miles. (*iii*) Bargarh—Hirakud—30 Miles.

Appendix II

TRAIN AND BUS SERVICE TO AND FROM HIRAKUD—(CALCUTTA—HIRAKUD—CALCUTTA)

Stations		Calcutta—Hirakud		
		Mail	Passenger	
		H.M.	H.M.	H.M.
		Calcutta—Bombay		
Howrah	d	19.15	8.55	21.45
Kharagpur	a	21-54	12.10	0.51
	d	22.5	12.25	1.6
Tatanagar	a	0.21	16.11	4.19
	d	0.32	16.26	4.34
Chakradharpur	a	1.46	18.25	6.21
	d	1.56	18.40	6.41
Jharsuguda	a	5.36	0.31	12.41
		Jharsuguda—Sambalpur.		
Jharsuguda	d	. .	6.30	15.15
Sambalpur	a	. .	9.0	17.45

Sambalpur-Hirakud
Distance=9 Miles Bus Service

Stations		Hirakud—Calcutta		
		Mail	Passenger	
		H.M.	H.M.	H.M.
		Hirakud—Sambalpur		
		Distance=9 Miles Bus Service		
		Sambalpur—Jharsuguda		
Sambalpur	d	. .	9.55	18.40
Jharsuguda	a	. .	12.29	21.5
		Bombay—Calcutta		
Jharsuguda	d	23.58	2.27	15.0
Chakradarpur	a	3.44	8.22	20.51
	d	3.44	8.37	21.6
Tatanagar	a	4.57	10.44	22.39
	d	5.8	10.59	22.54
Kharagpur	a	7.30	14.42	2.50
	d	7.41	14.57	3.5
Howrah	a	10.15	17.55	6.5

A (Sambalpur—Calcutta) through bogie with 1,2 & 3rd class is attached to the Bombay Mail every day on the up and down journey.

Appendix III

TRAIN AND BUS SERVICE TO AND FROM HIRAKUD (BOMBAY—HIRAKUD—BOMBAY)

Stations		BOMBAY—HIRAKUD		
		Mail	Passenger	
		H.M.	H.M.	H.M.
		BOMBAY—CALCUTTA		
Bombay	d	19-50	. .	. .
Nagpur	a	11-20	. .	. .
	d	11-50	5-50	21-15
Raipur	a	17-44	15-41	5-5
	d	17-55	15-56	5-20
Bilaspur	a	19-52	19-2	8-39
	d	20-2	19-17	8-54
Jharsuguda	a	23-46	2-12	14-45
		JHARSUGUDA—SAMBALPUR		
Jharsuguda	d		6-30	15-15
Sambalpur	a	. .	9-0	17-45
		SAMBALPUR—HIRAKUD		
		Distance=9 Miles Bus Service		

Stations		HIRAKUD—BOMBAY		
		Mail	Passenger	
		H.M.	H.M.	H.M.
		HIRAKUD—SAMBALPUR		
		Distance : 9 Miles Bus Service		
		SAMBALPUR—JHARSUGUDA		
Sambalpur	d	. .	9-55	18-40
Jharsuguada	a	.	12-29	21-5
		CALCUTTA—BOMBAY		
Jharsuguda	d	5-48	0-46	12-56
Bilaspur	a	9-22	6-30	18-52
	d	9-32	6-55	19-12
Raipur	a	11-17	9-41	22-18
	d	11-29	9-56	22-33
Nagpur	a	18-0	20-50	7-20
	d	18-25	. .	. .
Bombay	a	11-0	. .	. .

ARRIVAL OF MADRAS TRAINS AT NAGPUR

	Departure from Madras	Arrival at Nagpur
Grand Trunk Express.	12-0	10-15
Janata Express.	9-50	13-10

DEPARTURE OF MADRAS TRAINS FROM NAGPUR

	Departure from Nagpur	Arrival at Madras
Grand Trunk Express.	15-0	13-0
Janata Express.	14-25	18-35

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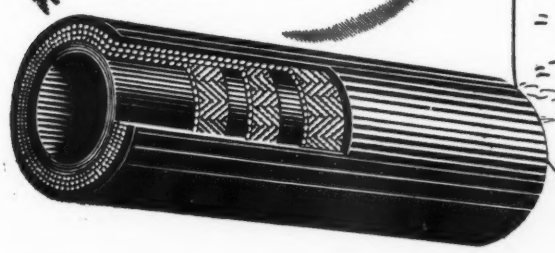

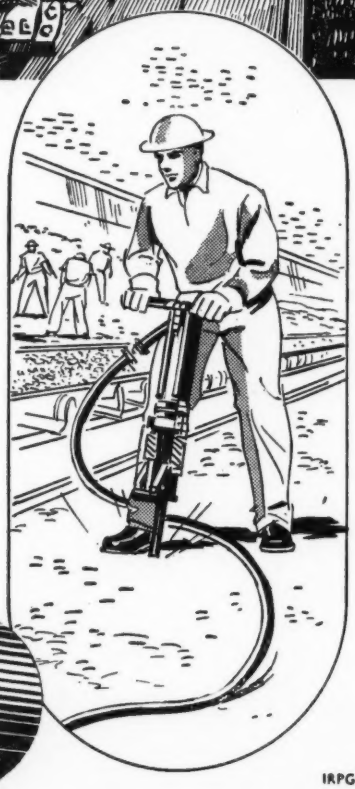

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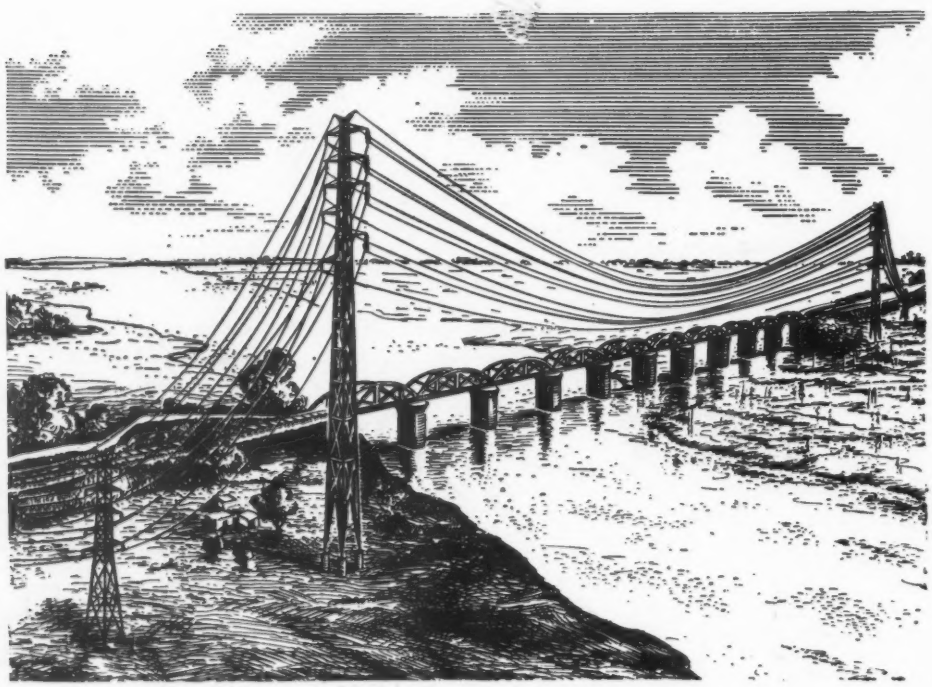

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